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Impact of Sault Ste. Marie East End Wastewater Treatment Plant Discharge on Lake George Channel (St. Marys River) Waters

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Ontario

Ministry of the Environment

Impact of Sault Ste. Marie East End Wastewater Treatment Plant Discharge on Lake George Channel (St. Marys River) Waters

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EXECUTIVE SUMMARY

This report provides a summary and assessment of data obtained during the 1989 Ontario Ministry of the Environment Sault Ste. Marie East End Wastewater Treatment Plant (WWTP) evaluation surveys. It includes a discussion and interpretation of the WWTP discharge and its impact on Lake George Channel receiving waters. Data included in this document cover the plant final effluent and river water quality monitoring conducted during the June and August surveys. Also included is flow, river current and plume tracking data, as well as bacterial densities and contaminant concentrations in surficial sediment samples collected during the second survey. Major findings and conclusions include:

(i) The discharge area for the WWTP is on a shallow shelf of less than 2 m depth, where currents are quite variable - but typically less than 10 $cm.sec^{-1}$, with variable direction of flow. Because of the shallowness, flow in the discharge area is more susceptible to influence by wind than the deeper, faster flowing waters of the main channel. For example, under northeast wind conditions, the direction of travel of drogues was initially perpendicular to shore, progressing to about 45 degrees relative to the shore for the first 200 m of travel. This can cause the WWTP discharge plume to impinge on U.S. waters (i.e., result in trans-boundary pollution).

(ii) The impact of the WWTP discharge on Lake George Channel water quality did not differ appreciably from earlier studies. During the six days of sampling during the two surveys, the East End WWTP design capacity was exceeded once, during a period of high rainfall on August 22nd. Plant discharge loadings were greatest for all measured parameters (suspended solids, chloride, bacteria (faecal coliforms, *Escherichia coli, Pseudomonas aeruginosa)*, ammonium, total Kjeldahl nitrogen, total phosphorus, phenolics, iron and zinc) on August 22nd, due to the high discharge rate and elevated levels in the final effluent. On this day, estimated loadings of faecal coliforms were up to 200 times greater, while suspended solids, ammonia, total Kjeldahl nitrogen, total phosphorus, iron and zinc loadings were up to two times greater than on the day with the lowest loading.

The impact of the WWTP discharge on Lake George Channel water quality was evident from data on faecal coliforms, *E. coli*, *Pseudomonas aeruginosa* conductivity, chloride, ammonia, total Kjeldahl nitrogen, total phosphorus, phenolics, iron and zinc, levels of which increased noticeably downstream of the discharge point during both surveys. The greatest effect on bacteria densities in river water was found on August 22nd and 23rd, during and immediately following the period of heavy rainfall. For example, faecal coliform densities exceeded the PWQO for the protection of recreational users as far as 4.7 km downstream (i.e., at Bell Point). (*E. coli* accounted for 42% to 85% of the fecal coliforms in the final effluent.) Total phosphorus exceeded the PWQO to prevent excessive aquatic plant growth in rivers for a distance of up to 0.9 km downstream of the

discharge point. Phenolics concentrations exceeded the PWQO to prevent tainting of fish at upstream as well as downstream locations, indicating the influence of sources located upriver of the WWTP.

(iii) Surficial sediments collected at 16 locations in Lake George Channel and in Little Lake George were generally very organic or "oozy" in nature, had an oily sheen, and often with a sewage or oily odour. Sediments from up to 2 km downstream of the WWTP discharge contained elevated (above upstream samples) densities of faecal coliform, *Escherichia coli* and faecal *Streptococcus* bacteria. Densities of these organisms reached as high as about 134,000, 14,400 and 21,000 organisms per kg of wet sediment. Concentrations of nutrients and persistent inorganic contaminants (e.g., heavy metals) usually increased downstream of the WWTP discharge, and concentrations were often higher at inshore stations than at offshore stations. Statistical analysis indicated that concentrations of arsenic, cyanide, heavy metals and many of the individual PAH compounds correlated significantly with one another, suggesting a common source. Concentrations of many of the contaminants in Lake George Channel and Little Lake George sediments, as well as at the upstream reference (i.e, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc, total PAHs and of 11 individual PAHs), exceeded the Lowest Effect Level Provincial Sediment Quality Guidelines for the protection of benthic organisms. This indicates that upstream sources contribute or have contributed to sediment quality problems in the Lake George Channel and in Little Lake George. In addition, concentrations of available cyanide at some stations exceeded the Provincial guideline for Open Water Dredged Material Disposal. Iron also exceeded the Provincial "Severe Effect Level" (SEL) sediment quality guideline at some stations. Total phosphorus only exceeded the PSQG-LEL at some stations downstream of the WWTP, but total Kjeldahl nitrogen exceed the PSQG-LEL on all but one transect.

Concentrations of solvent extractables exceeded the Provincial Open Water Dredged Material Disposal Guideline of 1,500 $mg.kg^{-1}$ at stations on downstream transects, as well as at the upstream reference stations, which had the highest concentration. This suggests a dominating influence from upstream sources.

A draft version of this document was provided to the Sault Ste. Marie District office staff and St. Marys River Remedial Action Plan coordinator in September, 1995

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1.0 INTRODUCTION AND BACKGROUND

1.1 Status of Sault Ste. Marie East End WWTP

The Sault Ste. Marie East End Wastewater Treatment Plant (WWTP) is a primary municipal facility with a design capacity of 54.55 x 10^3 $m^3.day^{-1}$ and an average daily flow of 42 x 10^3 $m^3.day^{-1}$. The discharge alternates between two adjacent 1.67 metre diameter pipes extending 152 m. from shore (Kleinfeldt, 1987) on a relatively shallow (1 to 2 m. depth) shelf in the Lake George Channel (Fig. 1). Combined with the hydrological characteristics of the area (see Section 1.2), this can lead to poor dispersion of the effluent (Fig. 2).

The WWTP was identified by the Upper Great Lakes Connecting Channels Study as an important point source of several contaminants to the St. Marys River (UGLCCS, 1989). These included: phosphorus, ammonia, chloride, oil and grease, certain metals, volatiles, polycyclic aromatic hydrocarbons, chlorinated phenols, chlorinated benzenes and chlorinated ethers as well as bacteria (OMOE, unpubl. 1986-87 data). In addition, the treatment capacity of the plant was frequently exceeded during periods of heavy rainfall (UGLCCS, 1989).

A major plant expansion, including new sludge handling facilities and phosphorus removal equipment, came on-line in April, 1989. Preliminary bench-scale testing indicated that final effluent suspended solids concentrations would be reduced substantially as a result of the phosphorus removal process. It was also anticipated that this would improve the efficiency of year-round chlorination and hence, significantly reduce bacterial levels in the discharge.

1.2 Water Quality Issues

During three 1986 and 1987 Ontario Ministry of the Environment (OMOE) MISA pilot site surveys, bacterial densities were elevated downstream of the East End WWTP outfall. The geometric mean fecal coliform density exceeded the Provincial Water Quality Objective (PWQO) for body contact recreation of 100 $organisms.dl^{-1}$ (UGLCCS,1988) as far away as Bell Point, about 5 km. downstream. During the same surveys, total phosphorus and ammonia concentrations also increased downstream of the WWTP outfall (e.g., Fig. 3). Similar results were observed in a 1988 survey conducted by the Ministry's Northeastern Region: elevated levels of turbidity, suspended solids and phosphorus were found up to 1 km downstream, and fecal coliform densities were above the PWQO for at least 3 km downstream of the discharge (Smith, 1988).

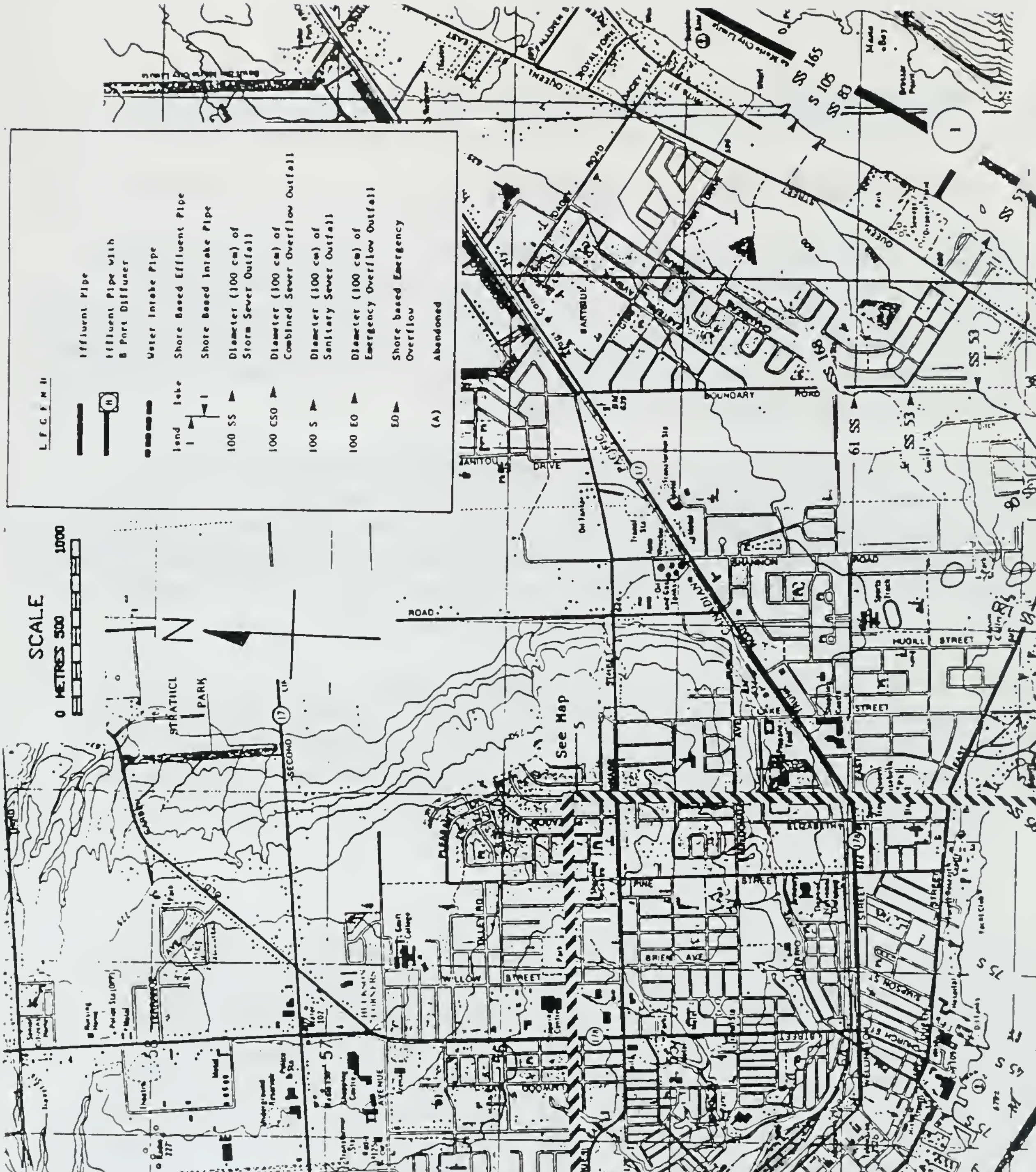

Figure 1. **Location of Sault Ste. Marie, Ontario East End WWTP and sewer discharges.** (from Kleinfeldt, 1987)

Figure 2. **Aerial view of the Sault Ste. Marie East End WWTP discharge plume, June 15, 1984.** (Source: Ontario Ministry of Natural Res., Ontario Centre for Remote Sensing).

Previous studies suggest that Canadian and American waters do not mix to an appreciable degree in the upper river or in the main channel above Sugar Island. Nevertheless, some transverse mixing does occur in the Lake George Channel due to the curving nature of the channel. This creates a zone of high velocity towards the Sugar Island (U.S.) shoreline and can lead to transboundary pollution, both from upstream sources as well as from the East End WWTP discharge (UGLCCS, 1989). For example, a 20% increase in ammonia concentrations was detected in U.S. waters of the channel downstream of the WWTP outfall in 1981 (Hamdy & LaHaye, 1983). Transboundary pollution was also detected during 1988 for turbidity, suspended solids, phosphorus and bacteria at distances of from 0.5 km to 3 km downstream of the outfall (Smith, 1988).

During 1988, complaints were received by the Ministry's Sault Ste. Marie district office from downstream waterfront residents regarding floating scum. In the fall of the same year, the end of an outfall pipe broke loose from its moorings and surfaced.

1.3 Sediment Quality Issues

Sediments immediately downstream of the WWTP outfall contain elevated concentrations of contaminants such as heavy metals (e.g., zinc, iron), solvent extractables and polycyclic aromatic hydrocarbons (Kauss, 1986, 1991). In 1985, the benthic macroinvertebrate community in this area was severely to moderately impaired, with an additional zone of moderate impairment extending downstream into Little Lake George as well as upper Lake George (Burt *et al.*, 1988; Fig. 4).

2.0 STUDY OBJECTIVES

(i) To determine the current (i.e., post-expansion) impact of the Sault Ste. Marie, Ontario East End WWTP discharge on St. Marys River water and sediment quality in relation to previous years.

(ii) To determine the variability of the zone of impact of the WWTP discharge plume.

(iii) To obtain data for the present outfall location (velocities, dispersion coefficients, chemistry) that will aid in modelling and design for a new outfall location/configuration and/or WWTP upgrading.

3.0 FIELD METHODS

Sampling was confined to two periods during 1989: June 27 - July 1 and August 20-24.

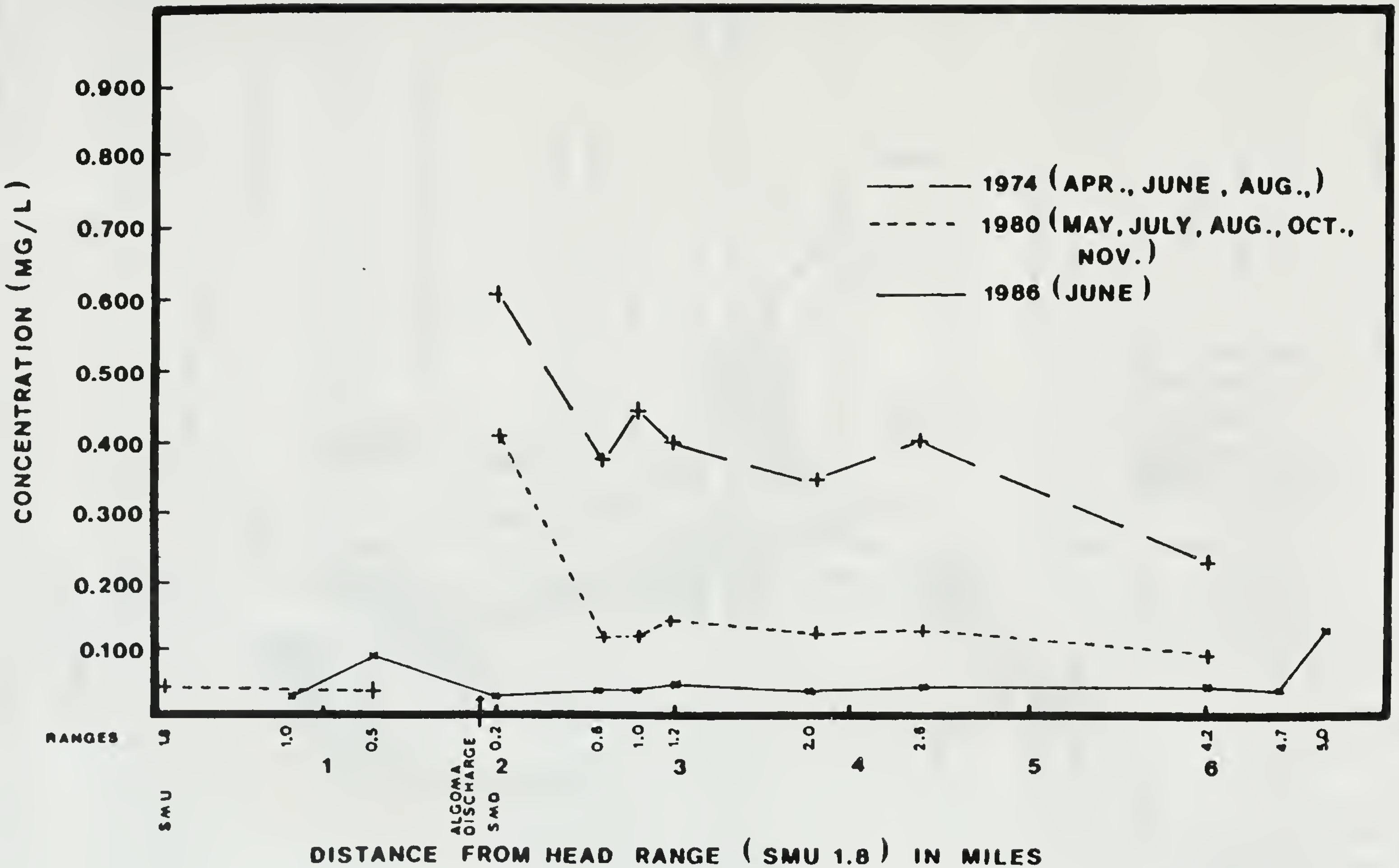

Figure 3. Ammonia distribution and yearly trends (1974, 1980 and 1986) along the Sault Ste. Marie, Ontario shoreline. (Source: OMOE data, in UGLCCS, 1989).

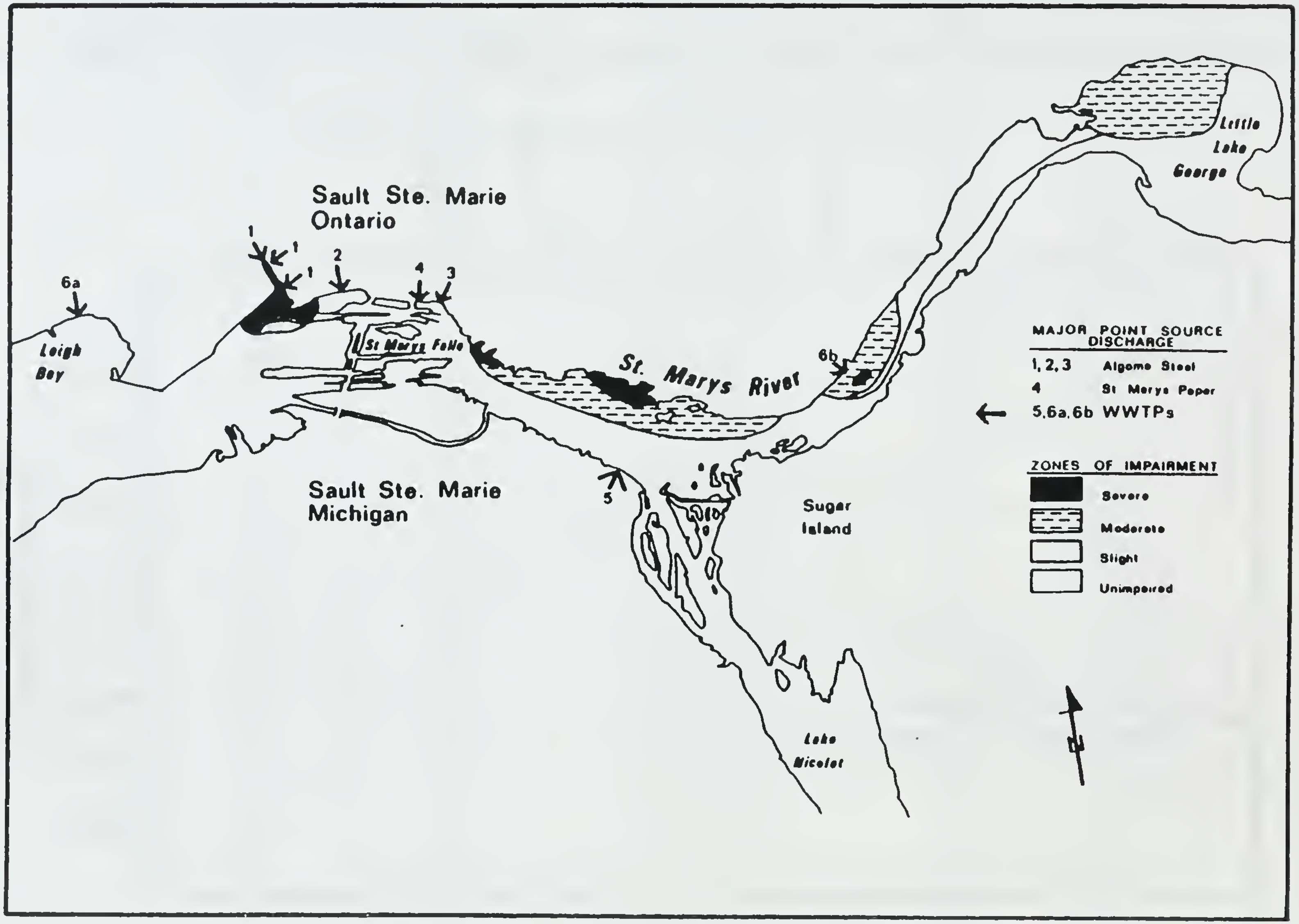

Figure 4. **Distribution and zones of impairment of benthic macroinvertebrate communities in the St. Marys River, 1985.** (Source: UGLCCS, 1989, after Burt *et al.*, 1988).

3.1 Physical Measurements

3.1.1 River Current Measurements

River current velocity and direction were measured (usually on the same day as chemistry) at 100 m intervals, starting at 100 m from the Canadian shore, along transects B, D, E, F, G and H (see Fig. 5). Data were collected using Anderaa Model RCM4S recording meters operated from the survey vessel, which was double-anchored (bow and stern).

At shallow stations (i.e., less than 2 m water depth) measurements were obtained at mid-depth only. Stations deeper than 2 m were measured at approximately 0.2 and 0.8 of total water depth. Stations were measured during six different days (three days during each of the two surveys). The period of current measurement was 10 minutes at each station/depth, with readings every 30 seconds.

Temperature and conductivity profiles were also obtained at each station.

3.1.2 Effluent Discharge Rate and Plume Tracking

During the period of river water quality sampling, discharge flow rate and temperature data were obtained for the WWTP final effluent. These measurements were made three times on each of the six survey days and were coincident with effluent chemistry sampling (see Section 3.2.1).

In addition to current measurements, the direction of the effluent plume was determined at the beginning of each survey day to aid in optimization of the river water sampling stations. Two drogues were released at the outfall discharge at mid-depth and tracked for a minimum of 30 minutes.

3.2 Effluent and River Sampling

Grab river water and effluent samples were collected on each survey day, using the appropriate bottles or containers and sample preservation techniques (OMOE, 1989).

3.2.1 Effluent Quality

Three grab samples of the WWTP final (treated) effluent were obtained during each of the six survey days using a pole sampler which held the bottles upright. Sampling was designed to coincide with the period of river water quality sampling (usually between 09:00 and 16:00 hours).

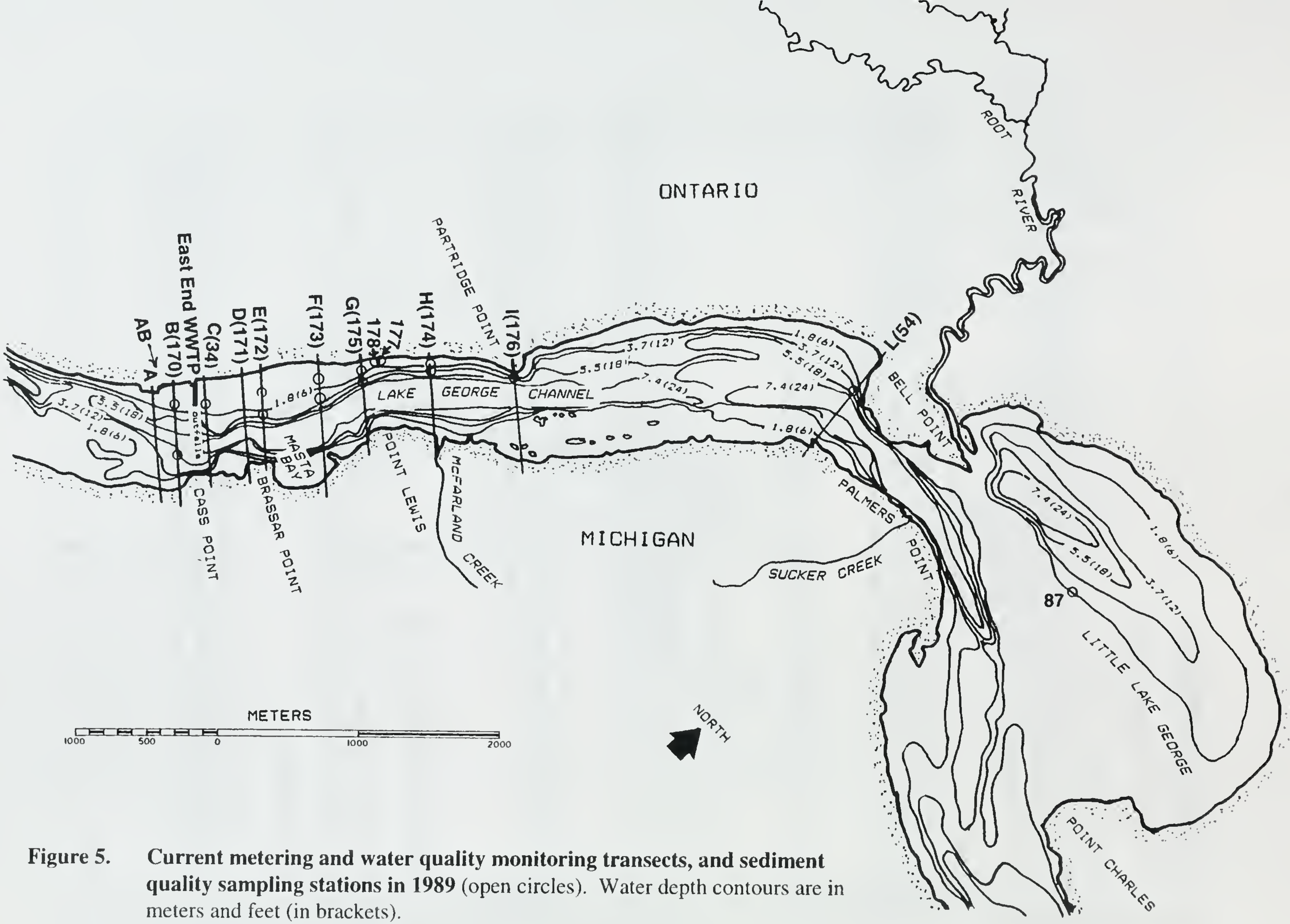

Figure 5. **Current metering and water quality monitoring transects, and sediment quality sampling stations in 1989** (open circles). Water depth contours are in meters and feet (in brackets).

3.2.2 River Water Quality

The 37 river water quality sampling stations were located along seven transects shown in Figure 5: B, C, D, E, F, H and L (Stations 170, 34, 171, 172, 173, 174 and 54, respectively). These were not always coincident with the current metering stations, the final locations being decided upon in the field each day, based on the results of effluent drogue tracking (see Section 3.1.2). Station descriptions are provided in Appendix Table A-1.

Grab river water samples were pumped from the desired depth using a March Model 5C MD submersible pump attached to a Teflon® -lined hose system that was cleaned before each day's sampling. Additionally, the system was flushed with sample water from each station/depth prior to taking the sample. Except for those bottles already containing preservatives, sample containers were first rinsed twice with sample water before keeping the sample.

At stations of less than 2 metres depth, a single sample was collected at mid-depth. With the exception of stations noted in Appendix Table A-1, two samples were collected at the deeper stations, one each at 0.2 and 0.8 of water depth.

Duplicate samples were also collected at three selected station depths on each of the six sampling days to provide data on within-station variability.

3.2.3 Surficial Sediment Quality

During the second survey, on August 20-22, surficial sediments were collected at 16 stations located mainly in Ontario waters of the Lake George Channel and in Little Lake George (see Fig. 5 and Appendix Table A-1).

A clean, sterilized* Shipek dredge was used to collect three samples at each station. The top 3 cm (central portion) of each of the replicates was removed with a sterilized* spoon and then all were composited and homogenized in a clean, sterilized* stainless steel pan.

After a known volume of sediment homogenate had been weighed to obtain the field (wet) weight, the remaining sediment was distributed among the required sample jars/containers and preserved as required (OMOE, 1989). Pre-sterilized (i.e., autoclaved) jars were used for bacterial submissions.

To provide data on within-station variability (e.g., heterogeneity) two additional replicate samples were obtained at two selected stations.

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* allowed to soak in alcohol between stations.

3.3 Field Quality Assurance

3.3.1 Effluent

Once during each of the two surveys, a split sample randomly selected from all nine possible samples/times, was submitted for all chemical and bacteriological tests to provide data on sample handling, preservation and transport, and on laboratory reproducibility.

3.3.2 River Water

During each of the six survey days, three split samples, randomly selected from all 37 possible stations/depths, were submitted for all chemical and bacteriological analyses. In addition, one "field blank" was obtained each day by pouring distilled water through the pump-hose sampling system and submitted for chemical analyses (not bacterial) only, to provide information on potential station-to-station cross-contamination.

Finally, for each of the two surveys, one distilled water "travel-blank" was obtained by filling the required bottles for chemical analyses at the Etobicoke laboratory and transporting them to the field and back to obtain information on potential background (container) contributions to observed measurements.

3.3.3 Surficial Sediment

At two stations randomly selected from the 14 sampled, enough sediment was collected to permit the submission of blind duplicate (split) samples for all analyses.

4.0 ANALYTICAL METHODS

All effluent, river water and sediment samples were submitted to the Ministry's Etobicoke Laboratory Services Branch and analyzed according to documented procedures (OMOE, 1983 and updates) for the parameters listed in Appendix A, Tables A-2 and A-3. Analytical methods and measurement capabilities are also included in the tables.

Analytical parameter selection was based on those effluent contaminants with the highest above-background (river) concentrations during the 1986/87 MISA pilot study surveys (Appendix Table A-2). Parameter selection was similar for sediments, with the additional objective of filling data gaps for certain contaminants (e.g., bacteria, arsenic, cyanide and polycyclic aromatic hydrocarbons).

5.0 RESULTS AND DISCUSSION

5.1 Physical Measurements

5.1.1 WWTP Discharge Rate

Data on water temperature and flow rate of the East End WWTP final effluent are provided in Table 1. It is noteworthy that the peak flow rate of 60,000 $m^3.d^{-1}$ was recorded during mid-day of August 22. A total 11.2 mm of rainfall was recorded at the Sault Ste. Marie, Ontario airport on this day (Appendix Table A-4).

5.1.2 River Water Temperature and Currents

Depth profile data on water temperature in the Lake George Channel are listed in Tables 2 and 4. These do not indicate any pronounced thermal stratification of the receiving waters during the two surveys.

Over the two survey periods, river current velocities were measured at a total of 26 stations. At 14 of these stations, velocities were measured at two different depths, (using two Anderaa RCM4S meters).

A basic statistical summary (i.e., mean, standard deviation, minimum and maximum) of the measured current velocities is provided in Table 2. This includes the results of measurements made during June 28-29, June 30, July 1, August 22, August 23 and August 24, respectively.

In Table 2, the "current heading" is the bearing angle between the current direction and the "Magnetic North" direction. This angle is positive if it is measured clockwise from North, and negative if it is measured counter-clockwise from North. During 1989, in the St. Marys River area, the "Magnetic North" direction was about seven degrees towards the West of "True (geographic) North". As examples of how the above applies to Table 2: a "current heading" of -128, -38, +52 and +142 degrees, means that the current is flowing towards the geographic SW, NW, NE and SE direction, respectively.

5.1.3 Plume Tracking

Although two drogues were released very near to the outfall location on each of the six days, some difficulties were experienced due to the shallow water conditions in the vicinity of the outfall. As a result, only nine of the 12 total releases provided useful plume tracking information.

The travel paths taken by the nine drogues are indicated in Figures 6 and 7. These Figures summarize results obtained during the six measurement days: June 27, June 28, June 29, August 22, August 23 and August 24, respectively.

Table 1. East End WWTP final effluent flow rate and quality.

Date	Time	Discharge Rate $10^3 m^3 day^{-1}$	Temperature °C	pH $-log_{10}[H^+]$	Turbidity FTU	Suspended Solids $mg.l^{-1}$	Conductivity $\mu mho.cm^{-1}$	Chloride $mg.l^{-1}$	Fecal coliforms $number.dl^{-1}$	*Escherichia coli* $number.dl^{-1}$	*Pseudomonas aeruginosa* $number.dl^{-1}$	Ammonium $mg.l^{-1}$	Kjeldahl Nitrogen $mg.l^{-1}$	Phosphorus $mg.l^{-1}$	Phenolics $\mu g.l^{-1}$	Iron $\mu g.l^{-1}$	Zinc $\mu g.l^{-1}$
June 27	10:25	38.5	16.0	7.46	11.30	21.0	730.0	87.40	75000	52000	1480	15.50	18.00	0.60	41.0	1200	31
"	11:25	40.0	16.5	7.92	9.20	20.7	729.0	91.20	2300	1700	<20	15.70	18.20	0.66	41.0	920	40
"	12:35	40.0	16.5	8.01	5.70	19.0	752.0	90.80	50000	33000	~33	20.02	23.10	0.64	47.0	710	32
"	mean	39.5	16.3	7.85	8.40	20.2	737.0	89.80	20508	14289	~79	17.00	19.63	0.63	42.9	922	34
June 28	--	38.0	16.0	7.87	10.10	20.3	738.0	87.30	77000	41000	300	17.10	19.70	0.84	48.0	1200	50
"	--	30.0	16.0	7.92	9.90	19.2	751.0	92.10	5300	4000	~117	17.80	20.90	0.84	45.0	830	34
"	--	30.0	16.0	7.92	11.40	21.3	766.0	88.30	6000	3600	~328	21.80	25.20	0.91	58.0	800	30
"	mean	32.5	16.0	7.90	10.40	20.2	752.0	89.20	13516	8939	~226	18.79	21.81	0.86	49.9	927	37
June 29	09:30	37.0	16.0	7.48	13.40	29.6	736.0	86.10	2200	920	~30	16.40	21.40	<u>1.02</u>	51.0	850	60
"	10:30	30.0	16.0	7.52	10.30	21.4	732.0	88.60	132000	55000	4600	16.20	19.80	0.80	51.0	--	46
"	11:30	31.0	16.0	7.37	9.50	18.2	700.0	90.20	13000	9000	2900	17.20	20.40	0.64	44.8	680	43
"	mean	32.5	16.0	7.46	10.94	22.6	722.0	88.28	15571	7694	~737	16.59	20.52	0.80	48.8	760	49
Aug. 22	11:00	36.0	20.0	7.16	8.90	21.1	638.0	75.20	72000	--	880	19.80	23.60	0.78	37.6	770	21
"	12:30	**60.0**	20.0	7.16	13.50	32.0	669.0	71.50	570000	--	3300	24.90	31.80	<u>1.30</u>	--	1200	36
"	14:00	48.0	20.0	7.15	19.00	45.3	653.0	66.50	1040000	--	7600	22.40	30.50	<u>2.42</u>	49.6	1200	62
"	mean	47.0	20.0	7.16	13.17	31.3	653.0	70.98	349473	--	2805	22.27	28.39	<u>1.35</u>	43.2	1035	36
Aug. 23	09:00	30.0	20.0	7.10	9.00	24.6	638.0	68.00	4700	--	220	19.70	24.90	0.85	46.0	880	24
"	10:00	37.0	20.0	7.02	9.00	31.7	643.0	72.20	35000	--	660	20.00	24.50	0.75	45.6	1000	21
"	11:00	37.0	20.0	7.51	10.90	26.2	643.0	74.10	5500	--	460	19.10	24.70	0.65	42.4	790	16
"	mean	34.5	20.0	7.27	9.59	27.3	641.3	71.39	10517	--	406	19.60	24.70	0.75	44.6	886	20
Aug. 24	09:00	30.0	20.0	7.25	15.20	31.5	636.0	67.50	1400	1000	~20	18.80	23.90	0.90	43.8	770	24
"	10:00	35.0	20.0	7.25	10.40	25.3	633.0	71.00	4300	2600	320	18.20	22.30	0.76	37.4	730	25
"	11:00	37.0	20.0	7.47	8.80	18.8	623.0	65.50	2000	1550	220	18.40	22.55	0.60	36.3	720	22
"	mean	33.9	20.0	7.34	11.16	24.6	630.6	67.96	2292	1591	~112	18.46	22.91	0.74	39.0	740	24
Study Mean		36.3	17.9	7.59	10.51	24.1	687.6	79.02	18201	6288	~345	18.70	22.82	0.83	44.6	872	32

NOTES: "mean" = geometric (log_{10}) mean
"--" = information or data not available (e.g., sample spoiled in laboratory accident).
< = less than.
~ = approximately.
Underlined values in shaded cells, if monthly averages, would exceed the GLWQA monthly average objective of 1 mg/l total phosphorus for sewage treatment plants (IJC, 1988)
Bolded discharge rate exceeds the design capacity.

Table 2. Summary of Lake George Channel current meter and temperature measurements.

Date	Transect (Station)	Distance from CDN shore, m	Meter Depth, m	Number of Readings	Temperature, °C				Current Heading, degrees				Current Speed, cm.s^{-1}			
					mean	s.d	min	max.	mean	s.d.	min.	max.	mean	s.d	min.	max
June 28	B (170)	100	0.5	23	9.4	0.04	9.3	9.4	41.9	45.93	57.7	110.4	3.7	3.26	1.5	12.7
"	"	200	1.5	30	9.0	0.05	9.0	9.1	59.2	9.50	28.4	85.6	28.6	5.32	12.7	40.7
"	"	300	1.0	25	9.0	0.04	8.9	9.0	55.3	3.09	50.4	63.6	51.2	1.86	46.3	51.9
"	"	"	4.5	24	8.9	0.03	8.9	9.0	56.6	3.95	50.0	66.1	40.2	4.64	29.5	46.3
"	"	400	1.5	25	9.0	0.03	8.9	9.1	68.2	8.59	47.2	86.0	32.4	4.00	23.9	40.7
"	"	"	4.5	25	9.0	0.03	9.0	9.1	69.0	8.84	47.6	81.1	29.5	3.23	23.9	35.1
"	"	500	1.0	18	9.4	0.00	9.4	9.4	57.1	17.93	24.9	83.9	8.7	5.97	1.5	18.3
"	"	"	2.0	20	9.4	0.05	9.4	9.6	27.8	21.80	-8.1	72.7	3.2	3.18	1.5	12.7
June 28	E (172)	100	0.5	17	10.8	0.11	10.7	11.0	168.7	37.77	120.9	255.2	3.5	3.89	1.5	12.7
"	"	200	"	21	10.8	0.11	10.6	10.9	205.7	104.1	20.3	327.3	7.1	5.29	1.5	18.3
"	"	300	1.0	21	10.9	0.06	10.8	11.0	217.3	86.55	33.6	336.9	3.6	3.29	1.5	12.7
"	"	400	3.0	24	9.4	0.04	9.3	9.5	49.8	2.58	42.3	54.5	47.7	2.47	46.3	51.9
"	"	"	10.0	19	9.3	0.06	9.3	9.5	42.7	6.46	33.3	55.2	29.8	3.46	23.9	35.1
"	"	500	2.0	26	9.8	0.18	9.4	10.1	39.0	8.31	20.3	52.5	33.2	5.24	29.5	46.3
"	"	"	8.0	18	9.5	0.05	9.4	9.5	42.3	14.26	14.1	62.9	21.1	9.18	1.5	29.5
June 29	F (173)	100	0.5	21	11.7	0.30	11.2	12.5	61.8	74.03	-54.7	209.5	2.0	1.67	1.5	7.1
"	"	200	1.0	19	10.8	0.41	10.4	11.8	21.2	35.79	38.1	73.7	1.8	1.28	1.5	7.1
"	"	300	"	19	9.8	0.12	9.7	10.2	13.4	14.37	-29.0	33.6	8.6	3.12	1.5	12.7
"	"	"	3.0	20	9.7	0.05	9.7	9.9	11.4	19.65	-17.9	59.1	6.5	2.55	1.5	12.7
"	"	400	2.0	19	9.8	0.03	9.8	9.9	32.6	2.90	24.9	36.4	40.4	1.28	35.1	40.7
"	"	"	8.0	18	9.8	0.00	9.8	9.8	20.2	5.20	13.7	36.1	28.9	3.75	23.9	35.1
"	"	500	2.0	19	10.1	0.05	10.0	10.2	39.4	6.58	16.5	46.2	23.0	2.08	18.3	23.9
"	"	"	7.0	17	9.9	0.04	9.9	10.0	34.6	5.15	21.4	44.1	18.0	1.35	12.7	18.3
June 29	G (175)	100	1.0	22	9.9	0.08	9.8	10.1	33.5	6.41	23.8	54.9	12.7	1.72	7.1	18.3
"	"	"	3.0	19	9.8	0.03	9.8	9.9	32.3	4.95	25.2	40.9	12.7	1.86	7.1	18.3
"	"	200	"	22	10.2	0.13	10.0	10.5	35.2	2.44	31.5	42.3	39.4	2.40	35.1	40.7
"	"	"	11.0	21	10.0	0.00	10.0	10.0	26.3	6.62	14.1	38.8	17.0	5.55	7.1	23.9
"	"	300	2.0	20	10.3	0.05	10.2	10.3	18.9	5.60	8.8	29.1	32.3	3.38	29.5	40.7
"	"	"	8.0	21	10.1	0.10	9.9	10.2	51.9	0.43	50.7	52.5	8.2	4.18	1.5	18.3
June 29	H (174)	100	1.0	25	10.1	0.06	10.1	10.4	39.4	2.35	32.6	44.1	31.7	3.61	23.9	35.1
"	"	"	4.0	25	10.1	0.03	10.1	10.2	38.9	3.32	32.2	44.8	27.9	3.03	23.9	35.1
"	"	200	2.5	23	10.2	0.05	10.2	10.3	49.1	2.45	44.1	53.5	33.2	2.72	29.5	35.1
"	"	"	9.5	22	10.2	0.05	10.1	10.2	52.7	4.78	43.7	64.3	16.0	3.71	7.1	23.9
"	"	300	2.0	22	10.4	0.11	10.2	10.6	9.7	24.05	-40.2	38.5	5.8	2.95	1.5	12.7
"	"	"	7.0	20	10.0	0.07	9.9	10.1	-6.0	24.37	-48.9	32.2	6.8	2.19	1.5	12.7
"	"	400	1.0	20	10.8	0.12	10.5	11.0	-59.9	78.90	-206.	82.8	2.1	1.71	1.5	7.1

Table 2. continued.

Date	Transect (Station)	Distance from CDN. shore, m	Meter Depth, m	Number of Readings	Temperature, °C				Current Heading, degrees				Current Speed, cm.s⁻¹			
					mean	s.d.	min	max.	mean	s.d.	min.	max.	mean	s.d.	min.	max.
June 30	B (170)	100	0.5	27	9.8	0.03	9.8	9.9	41.5	8.63	24.2	72.3	13.1	1.50	12.7	18.3
"	"	200	1.0	18	9.6	0.11	9.5	10.0	67.0	1.45	64 3	69.6	43.8	2.84	40.7	46.3
"	"	"	4.0	20	9.5	0.02	9.5	9.6	63.3	6.47	54.5	80.7	31.2	3.66	23.9	35.1
"	"	300	1.0	20	9.4	0.00	9.4	9.4	70.3	3.76	63.6	76.2	57.5	2.55	51.9	63.1
"	"	"	4.0	21	9.4	0.05	9.3	9.4	68.4	4.41	55.6	74 1	46.3	3.94	40.7	51.9
"	"	400	1.0	20	9.4	0.02	9.4	9.5	60.1	5.11	50.0	72.7	30.3	2.72	23.9	35.1
"	"	500	0.5	19	9.7	0.00	9.7	9.7	70.0	8.57	47.2	86.7	17.7	2.55	12.7	23.9
"	"	600	"	19	10.4	0.13	10.2	10.7	37.5	8.20	20.3	59.8	22.4	4.48	7.1	23.9
June 30	E (172)	100	0.5	19	10.6	0.05	10.6	10 7	31.6	51.86	-63 2	116.7	4.2	3.88	1.5	12.7
"	"	200	"	18	10.1	0.05	10.6	10.1	44.4	25.95	2.2	91.9	10.2	3.42	7.1	18.3
"	"	300	1.0	19	9.6	0.08	9.6	9.9	54.0	2.57	49.0	58.7	43.1	2.82	40.7	46.3
"	"	"	4.0	20	9.5	0.02	9.5	9.6	46.8	6.94	32.2	56.6	31.7	3.34	29.5	40.7
"	"	400	1.5	19	9.6	0.08	9.5	9.6	48.5	5.71	34 3	59.1	42.8	5.62	35.1	51.9
"	"	"	6.5	21	9.5	0.06	9.5	9.7	37.1	12.00	15.8	61.2	29.2	6.22	18.3	40.7
"	"	500	2.0	19	10.0	0.19	9.7	10.2	32.6	21.36	-16.1	65.7	26.0	3.81	18.3	29.5
"	"	"	8.0	16	9.8	0.06	8.7	9.9	44.4	16.74	16.5	85.6	22.2	3.33	12.7	23.9
June 30	F (173)	100	0.5	19	11.5	0.02	11.5	11.6	371.1	53.34	305.5	495.9	2.1	1.75	1.5	7.1
"	"	200	1.0	17	10.9	0.14	10.8	11 5	46.0	69.41	-44.7	139.4	6.8	4.99	1.5	18.3
"	"	300	"	23	9.9	0.03	9.9	10.0	39.8	21.04	5.0	67.8	27.3	5.25	18.3	35.1
"	"	400	3.0	18	9.6	0.06	9.6	9.8	47.5	4.51	38.8	55.6	36.7	6.54	23.9	46.3
"	"	"	10.0	20	9.5	0.04	9.5	9.6	34.0	13.64	4.6	58.4	23.3	8.06	7.1	35.1
"	"	500	1.5	20	10.0	0.06	9 9	10.1	38.6	39.22	-48.6	92 9	13.8	5.60	7.1	23.9
"	"	"	6.5	20	9.9	0.06	9.8	10.0	46.1	44.77	-19.3	129 2	11.3	4.73	1.5	18.3
June 30	G (175)	100	1.0	20	10.0	0.14	9.8	10.2	1.4	56.94	-131.	86.3	9.1	5.50	1.5	18.3
"	"	"	4.0	16	9.8	0.07	9.7	9.9	37.2	51.78	-43.0	156.5	7.8	4.46	1.5	12.7
"	"	200	3.0	21	10.2	0.25	9.8	10.7	39.4	7.79	27.3	52.8	39.6	6.74	29.5	51.9
"	"	"	11.0	18	9.7	2.10	9.7	10.6	32.9	10.51	20.0	47.2	38.8	9.14	29.5	46.3
"	"	300	2.0	20	10.0	0.07	9.9	10.1	20.4	26.33	-16.1	75.5	29.5	5.99	12.7	40.7
"	"	"	8.0	21	10.0	0.08	9.9	10.1	23.2	39.35	-29.7	101.0	21.2	6.26	12.7	35.1
June 30	H (174)	100	1.5	21	9.9	0.07	9.7	9.9	42.5	10.62	20.3	60.8	35.9	2.00	35 1	40.7
"	"	"	5.5	22	9.7	0.06	9.6	9.8	40.5	17.95	-6.4	67.5	29.2	6.55	12.7	35.1
"	"	200	3.0	20	9.9	0.05	9.9	10.0	49.8	13.73	21.0	75.5	35.7	4.00	29.5	40.7
"	"	"	10.0	20	9.7	0.05	9.7	9.8	54.4	17.95	21.4	98.5	32 9	4.20	23.9	40.7
"	"	300	1.5	19	10.4	0.08	10.2	10.5	-12.7	66.70	-86.3	110.7	7.1	3.70	1.5	12.7
"	"	"	6.5	19	9.9	0.04	9.8	10.0	45.5	89.17	-67.8	163.8	7.1	4.54	1.5	12.7
"	"	400	1.0	21	10.6	0.14	10.3	10.9	164.0	106.8	8.5	320.8	1.8	1.21	1.5	7.1

Table 2. continued.

Date	Transect (Station)	Distance from CDN. shore, m	Meter Depth, m	Number of Readings	Temperature, °C				Current Heading, degrees				Current Speed, cm.s^{-1}			
					mean	s.d.	min.	max.	mean	s.d.	min.	max	mean	s.d.	min.	max.
July 1	B (170)	100	0.5	18	11.0	0.09	10.9	11.3	48.7	3.49	43.4	56.6	11.1	2.58	7.1	12.7
"	"	200	1.5	18	11.0	0.03	10.9	11.1	61.6	2.22	57.0	64.3	35.7	1.81	35.1	40.7
"	"	"	5.0	19	10.9	0.03	10.9	11.0	57.1	3.94	49.7	64.3	29.5	3.23	23.9	35.1
"	"	300	1.5	21	11.0	0.05	11.0	11.1	68.1	2.82	58.7	72.0	41.5	4.44	29.5	46.3
"	"	"	5.0	20	11.0	0.00	11.0	11.0	67.5	5.04	55.9	77.6	29.2	4.25	23.9	35.1
"	"	400	1.5	22	11.1	0.00	11.1	11.1	64.0	6.14	47.9	73.4	21.9	3.25	18.3	29.5
"	"	"	5.0	20	11.1	0.00	11.1	11.1	62.1	9.24	50.4	80.7	7.7	3.09	1.5	12.7
"	"	500	1.0	19	11.2	0.03	11.2	11.3	50.9	15.66	10.9	72.3	8.0	3.37	1.5	12.7
"	"	600	1.0	16	11.1	0.06	11.1	11.3	46.6	5.40	35.7	57.0	12.4	1.40	7.1	12.7
"	"	"	3.0	19	11.1	0.00	11.1	11.1	40.2	5.21	30.8	50.0	11.2	3.15	7.1	18.3
July 1	E (172)	100	0.5	21	11.7	0.06	11.6	11.8	32.8	36.52	-22.4	102.7	1.5	0.00	1.5	1.5
"	"	200	"	19	11.5	0.05	11.4	11.5	66.6	17.43	47.6	105.9	5.9	2.33	1.5	7.1
"	"	300	1.0	18	11.2	0.08	11.2	11.5	54.8	1.88	51.4	58.0	29.2	1.31	23.9	29.5
"	"	"	4.0	19	11.1	0.00	11.1	11.1	53.3	2.96	48.6	59.1	23.9	1.86	18.3	29.5
"	"	400	2.0	19	11.2	0.04	11.1	11.2	49.2	4.01	38.1	58.4	35.7	4.50	23.9	40.7
"	"	"	9.0	20	11.1	0.02	11.1	11.2	42.1	9.87	14.8	55.6	27.0	4.94	18.3	35.1
"	"	500	1.5	18	11.2	0.04	11.2	11.3	103.5	30.11	31.9	142.8	2.1	1.79	1.5	7.1
"	"	"	5.5	19	11.2	0.00	11.2	11.2	197.2	47.61	99.6	346.7	1.5	0.00	1.5	1.5
July 1	F (173)	100	0.5	20	12.7	0.05	12.6	12.8	257.6	15.12	217.9	287.3	1.8	1.24	1.5	7.1
"	"	200	"	19	11.9	0.08	11.9	12.1	87.9	25.55	63.6	150.2	1.8	1.27	1.5	7.1
"	"	300	1.0	18	11.5	0.06	11.5	11.7	44.9	28.02	15.5	143.5	7.1	1.91	1.5	12.7
"	"	400	2.0	16	11.3	0.07	11.2	11.5	47.2	3.01	42.3	52.8	32.7	3.48	23.9	35.1
"	"	"	9.0	20	11.2	0.02	11.2	11.3	46.4	4.27	39.2	52.8	24.5	3.57	18.3	29.5
"	"	500	2.0	17	11.4	0.05	11.3	11.5	46.6	5.68	38.1	55.6	24.9	4.03	18.3	29.5
"	"	"	7.0	19	11.3	0.04	11.3	11.4	50.6	12.72	20.0	68.5	15.9	2.82	12.7	18.3
July 1	G (175)	100	1.0	19	11.2	0.08	11.2	11.5	33.8	17.30	7.4	60.8	11.2	2.52	7.1	12.7
"	"	"	3.5	19	11.2	0.05	11.2	11.4	36.5	21.24	2.9	67.5	10.0	2.86	7.1	12.7
"	"	200	3.0	19	11.3	0.05	11.2	11.4	27.8	5.44	19.0	42.7	30.7	2.33	29.5	35.1
"	"	"	11.0	19	11.2	0.03	11.2	11.3	34.6	10.71	16.2	58.4	18.0	4.34	7.1	23.9
"	"	300	2.0	19	11.5	0.03	11.4	11.5	6.1	38.12	-47.9	89.1	9.2	4.98	1.5	18.3
"	"	"	8.0	21	11.4	0.05	11.3	11.4	32.1	39.27	-33.2	92.2	6.6	4.28	1.5	12.7
July 1	H (174)	100	1.0	19	11.4	0.06	11.3	11.5	37.0	5.00	28.4	46.5	23.3	1.75	18.3	23.9
"	"	"	4.0	20	11.3	0.05	11.2	11.5	26.1	36.47	-59.1	86.7	5.4	3.66	1.5	12.7
"	"	200	2.5	21	11.5	0.04	11.4	11.6	45.8	11.38	7.4	69.9	27.1	4.52	12.7	35.1
"	"	"	10.0	21	11.4	0.04	11.4	11.5	51.5	14.86	10.9	77.9	21.2	2.86	18.3	23.9
"	"	300	1.5	21	11.7	0.26	11.4	12.2	39.6	73.75	-130.0	138.0	2.0	1.67	1.5	7.1
"	"	"	6.5	21	11.3	0.05	11.3	11.5	66.8	71.87	-74.8	184.0	2.0	1.67	1.5	7.1
"	"	400	1.0	16	11.7	0.11	11.6	11.9	47.1	42.00	-33.6	119.5	2.2	1.88	1.5	7.1

Table 2. continued.

Date	Transect (Station)	Distance from CDN. shore, m	Meter Depth, m	Number of Readings	Temperature, °C mean	s.d.	min.	max.	Current Heading, degrees mean	s.d.	min.	max.	Current Speed, $cm.s^{-1}$ mean	s.d.	min.	max.
August 22	B (170)	148	1.5	23	16.9	0.02	16.8	16.9	55.0	8.32	33.3	67.1	12.5	8.00	1.5	29.5
"	"	252	1.0	23	16.7	0.06	16.7	16.9	62.4	2.09	57.0	66.1	53.1	4.03	40.7	57.5
"	"	"	4.0	24	16.7	0.02	16.7	16.8	60.1	5.29	49.3	71.3	47.0	4.37	35.1	51.9
"	"	380	1.0	25	16.7	0.06	16.7	16.9	63.1	14 27	41.6	105.9	16.7	7.52	1.5	29.5
"	"	"	3.0	20	16.7	0.09	16.7	17.1	50.0	20.59	15.8	87.7	5.1	3.20	1.5	12.7
"	"	600	1.5	21	16.8	0.06	16.7	16 9	60.0	7.85	31.2	71.6	4.4	2.80	1.5	7.1
August 22	E (172)	200	0.5	18	17.2	0.04	17 1	17.2	195.3	41.07	138 3	317.3	1.5	0 00	1.5	1.5
"	"	300	1.0	22	17.0	0.06	16.9	17.1	70.2	4.17	63.6	80.4	4 8	2.75	1.5	7.1
"	"	"	3.0	17	16.9	0.00	16.9	16.9	53.1	27.26	-50.7	71.6	5.1	2.68	1.5	7.1
"	"	410	1.5	21	16.8	0.04	16.7	16.8	49.4	2.60	43.4	54.2	48.7	2.77	46.3	51.9
"	"	"	5.0	21	16.7	0.03	16.7	16.8	45.3	4.51	33.3	52.1	45.8	1.64	40.7	46.3
"	"	525	1.5	23	16.8	0.05	16.8	16.9	39.4	11.53	15.1	64.7	11.0	5.07	7.1	23.9
"	"	"	4 5	23	16.8	0.03	16.8	16.9	35.8	12.54	10 9	58.7	10.8	5.12	1.5	23 9
August 23	B (170)	186	1.5	20	16.8	0.11	16.8	17.2	60.6	5.83	42.0	73.7	33.3	4.09	23.9	40.7
"	"	300	"	20	16.8	0.02	16.8	16.9	62.6	2.54	58.2	68.5	59.3	5.02	42.6	63.1
"	"	400	1.0	19	16.9	0.02	16.9	17.0	83.9	8.76	71.3	99.6	3.0	2.47	1.5	7.1
"	"	470	1.5	22	17.0	0.05	17 0	17.1	71.0	8.15	54.9	93.3	4 0	2.79	1.5	7.1
"	"	630	"	22	17.1	0.02	17.0	17.1	57.9	5.61	51.8	79.3	11.7	2.74	1.5	12.7
August 23	D (171)	100	4.0	21	19.7	0.04	19 6	19.8	232.7	27.97	170.4	281.0	1.8	1.19	1.5	7.1
"	"	200	0.75	24	18.9	0.05	18.8	19.0	220.5	41.50	171.8	332.4	1.7	1.12	1.5	7.1
"	"	304	1.5	21	17.6	0.12	17.4	17.9	30.4	18.58	-10.5	53.9	6.8	3.66	1.5	12.7
August 23	E (172)	200	1.0	16	17.1	0.20	16.9	17.6	337.0	25.80	297.1	375.5	1.9	1.36	1.5	7.1
"	"	300	2.0	19	17.0	0.04	17.0	17.1	58.3	35.57	12.0	142.5	1.8	1.25	1.5	7.1
"	"	404	"	18	17.1	0.12	17.0	17.5	49.7	2.00	46.5	55.2	47.9	2.51	46.3	51.9
"	"	"	8.0	22	16.9	0.02	16.9	17.0	41.7	3.20	35.7	46.9	41.0	3.57	35.1	46.3
"	"	580	1.5	21	17.1	0.05	17.1	17.2	57.7	35.87	-27.6	140.4	10.3	7.04	1.5	29.5
"	"	"	6.5	23	17.0	0.05	17.0	17.1	48.0	37.84	-59.4	105.5	10.3	5.43	1.5	18.3
August 23	F (173)	100	1.0	20	17.3	0.05	17.2	17.4	239.0	41.43	136.2	293.3	1.5	0.00	1.5	1.5
"	"	220	1.75	21	17.1	0.05	17.1	17.2	329.5	48.20	135.5	393.6	2.6	2.20	1.5	7.1
"	"	300	2.0	23	17.2	0.05	17.1	17.4	29.8	5.27	18.3	39.2	34 1	5.13	18.3	40.7
"	"	"	9.0	25	17.0	0.02	17.0	17.1	15.0	16.29	-36.0	38.8	26.8	8.55	7.1	35.1
"	"	404	2.5	21	17 2	0.05	17.2	17.4	17.9	36 01	-29.4	99.2	8 2	8.40	1.5	23.9
"	"	"	9.5	23	17 2	0 03	17.1	17.2	28.4	25.17	-9.8	103.1	12.2	6.99	1.5	23.9
August 23	G (175)	100	1.0	19	17.3	0.04	17.3	17.5	35.5	9.95	11.3	51.1	11.2	3.56	7.1	18.3
"	"	"	3.0	21	17 2	0.06	17.2	17.4	49.4	14.10	23.5	77.2	6.0	3.29	1.5	12.7
"	"	200	2.5	26	17.2	0.00	17.2	17.2	32.1	3.91	22.1	39.5	37.3	3.14	29.5	40.7
"	"	"	10.0	29	17.1	0.05	17.1	17.2	28.9	12.28	-25.9	43.4	28.5	4.89	12.7	35.1
"	"	266	2.0	24	17.3	0.06	17.2	17.4	24.7	5.82	12.0	32.6	30.9	5.66	23.9	40.7
"	"	"	8.0	25	17.2	0.00	17.2	17.2	19.8	14.15	-6.7	41.6	17.0	6.58	1.5	23.9

Table 2. continued.

Date	Transect (Station)	Distance from CDN. shore, m	Meter Depth, m	Number of Readings	Temperature, °C				Current Heading, degrees				Current Speed, cm.s^{-1}			
					mean	s.d.	min.	max.	mean	s.d.	min.	max.	mean	s.d.	min.	max
August 24	AB (--)	100	0.1	18	16.6	0.48	15.9	17.0	283.2	87.19	129.2	369.9	2.4	2.80	1.5	12.7
"	"	200	1.0	20	17.0	0.05	16.9	17.1	65.8	2.85	59.8	70.6	46.0	1.22	40.7	46.3
"	"	"	3.0	16.0	17.0	4.12	17.0	17.0	66.5	16.44	58.4	70.6	39.0	9.74	35.1	40.7
"	"	300	1.5	18	17.0	0.00	17.0	17.0	61.9	2.62	56.6	67.5	60.9	2.73	57.5	63.1
"	"	404	0.75	14	17.1	0.10	16.7	17.1	83.2	44.47	-64.6	134.1	5.1	3.42	1.5	12.7
"	"	620	1.0	24	17.1	0.03	17.1	17.2	68.0	8.06	54.9	93.6	16.7	4.11	12.7	29.5
"	"	"	3.0	19	17.0	0.04	17.0	17.1	55.8	7.52	36.1	65.4	12.1	3.09	7.1	18.3
August 24	D (171)	100	0.5	20	18.6	0.33	17.8	19.3	314.2	43.48	255.6	387.7	1.5	0.00	1.5	1.5
"	"	200	0.75	18	18.2	0.13	17.9	18.3	209.7	77.76	47.9	307.6	2.7	2.33	1.5	7.1
"	"	300	1.5	21	17.6	0.28	17.0	18.0	61.9	22.18	29.1	103.8	8.4	4.54	1.5	18.3
August 24	E (172)	86	0.3	17	16.5	0.12	16.4	17.0	194.3	42.14	144.2	263.9	1.5	0.00	1.5	1.5
"	"	200	0.75	19	16.8	0.28	16.1	17.0	216.7	58.31	134.5	323.3	2.1	1.72	1.5	7.1
"	"	330	2.0	19	17.2	0.08	16.9	17.3	38.8	15.54	16.9	74.1	23.3	4.02	12.7	29.5
"	"	"	5.0	17	17.1	0.07	16.9	17.2	34.4	15.38	7.4	65.0	20.9	4.35	12.7	23.9
"	"	423	2.0	18	17.1	0.00	17.1	17.1	50.1	4.86	38.8	57.3	28.6	2.80	23.9	35.1
"	"	"	8.0	15	17.0	0.04	17.0	17.1	45.2	9.91	26.3	64.0	16.8	6.62	7.1	29.5
"	"	580	2.0	20	17.1	0.04	16.9	17.1	44.6	9.92	27.0	62.6	27.3	5.43	7.1	35.1
"	"	"	7.0	16	17.0	0.12	16.6	17.1	36.8	11.87	14.1	64.0	19.3	6.92	1.5	29.5
August 24	F (173)	100	1.0	20	17.2	0.22	16.7	17.3	263.4	74.25	155.4	373.7	2.3	2.00	1.5	7.1
"	"	214	1.5	22	17.2	0.19	17.1	17.8	310.3	45.99	190.0	366.4	8.9	4.27	1.5	12.7
"	"	300	2.0	20	17.2	0.08	17.2	17.5	29.1	6.80	17.9	47.2	28.9	3.50	18.3	35.1
"	"	"	8.0	16	17.1	0.02	17.1	17.2	24.9	11.35	2.5	51.4	28.5	4.52	12.7	35.1
"	"	406	2.0	21	17.2	0.07	16.9	17.3	22.1	5.14	13.4	32.2	33.0	8.01	12.7	40.7
"	"	"	6.0	15	17.2	0.05	17.1	17.2	20.4	9.27	8.8	47.6	28.8	2.79	23.9	35.1
August 24	G (175)	~100	1.0	27	17.3	0.10	16.9	17.5	33.0	7.28	18.3	59.1	11.2	4.20	1.5	18.3
"	"	"	3.0	27	17.1	0.12	16.8	17.2	30.4	16.84	-42.3	50.4	7.4	4.78	1.5	21.7
"	"	200	2.5	21	17.2	0.00	17.2	17.2	33.3	2.92	27.3	40.6	30.0	3.41	18.3	35.1
"	"	"	10.5	20	17.1	0.12	16.8	17.2	29.9	10.28	10.2	47.2	19.4	11.00	1.5	29.5
"	"	285	2.0	20	17.2	0.00	17.2	17.2	21.3	6.40	2.5	30.5	28.1	3.49	23.9	35.1
"	"	285	8.0	19	17.1	0.18	16.7	17.2	40.4	10.27	20.0	60.1	13.3	6.77	1.5	23.9

NOTES: "mean" = arithmetic mean.
"s.d." = standard deviation.
"~" = approximately.
Transect "AB" is located approximately midway between Transects "A" and "B"

5.1.4 *Interpretation of River Current and Plume Tracking Results*

Reviewing the measured river current data from all dates, it can be readily seen that the river flow regime can be split into two general classes, namely "strong" and "weak".

The "strong" flow regime is characterized by: a relatively large mean current speed of over 20 $cm.sec^{-1}$ near the surface; a mean flow direction coincident with the mean downstream direction of the river; and, relatively small standard deviations of both the current direction and current speed (i.e., with respect to their mean values). This regime occurs in the deeper portions of the river. Stations typical of this regime include:

Transect B - 200, 300, 400	metres from the Ontario shore
Transect E - 400, 500	"
Transect F - 400, 500	"
Transect G - 200, 300	"
Transect H - 100, 200	"

The "weak" flow regime is characterized by: a relatively small mean current speed of under 10 $cm.sec^{-1}$, and relatively large standard deviations of both the current direction and current speed (i.e., with respect to their mean values). This regime is particularly prevalent over the shallow "shelf" region, on the north side of the river where the outfall discharges. Stations typical of this regime include:

Transect B - 100	metres from the Ontario shore
Transect D - 100, 200, 300	"
Transect E - 100, 200	"
Transect F - 100, 200, 300	"

As can be seen from Figures 6 and 7, the drogues followed different travel paths from the outfall, depending upon daily wind conditions. Some general characteristics of these paths are summarized as follows:

- The paths are approximately parallel to shore (in the downstream direction) under SW and ESE wind directions (e.g., June 27 and August 22).

- The paths tend to run initially outward from shore at an approximate angle of 45 degrees for the first 200 metres or so of travel, under NE wind conditions (e.g., June 28, August 23 and August 24).

- The paths become parallel to the mean downstream river direction, after they reach the deeper portion of the river, (see August 23 and 24).

It may be concluded that, due to its "weaker" nature, the flow over the shallow "shelf" (where the outfall discharges) is more susceptible to wind variation than the deeper, faster-flowing waters of the main channel.

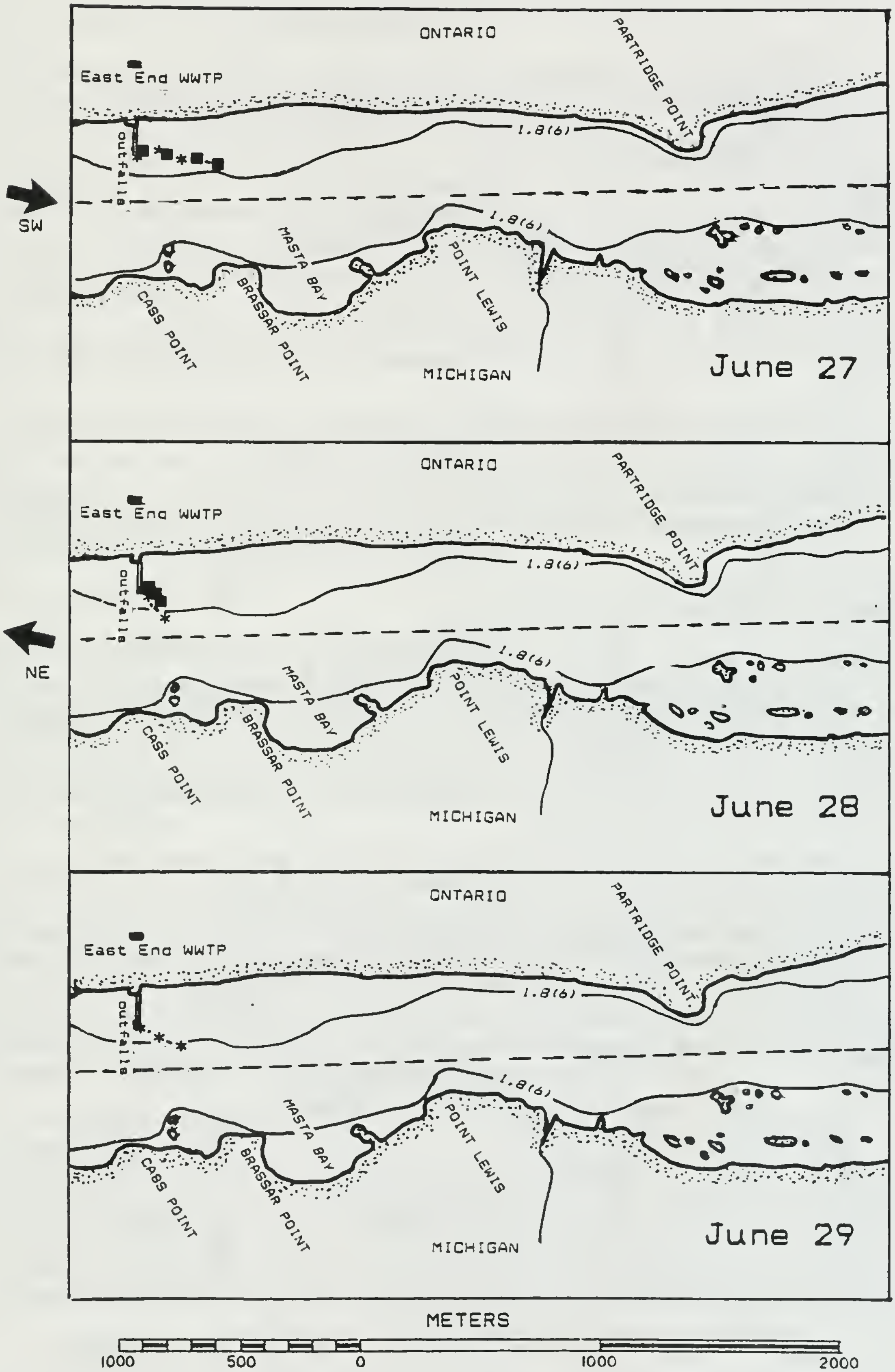

Figure 6. **Drogue travel paths (* and ■) on June 27, 28 and 29, 1989.** The 1.8 metre (6 foot) water depth contour and average wind direction are included. The dashed line represents the Canada-United States border.

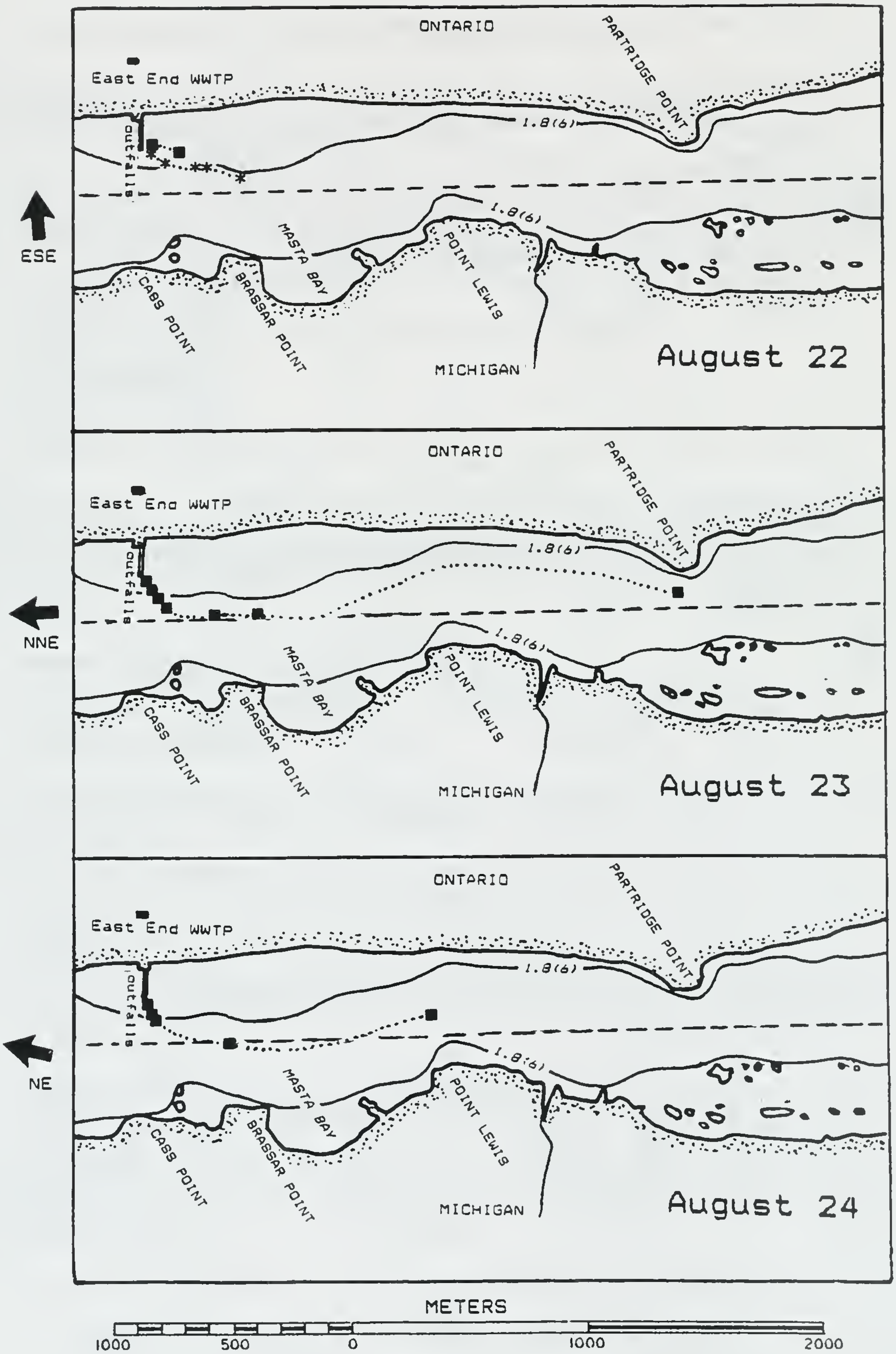

Figure 7. **Drogue travel paths (* and ■) on August 22, 23 and 24, 1989.** The 1.8 metre (6 foot) water depth contour and average wind direction are included. The dashed line represents the Canada-United States border.

5.2 Bacterial and Chemical Measurements

The maximum coefficients of variation (CV) for conventional chemical parameters in 19 pairs of blind duplicate (split) effluent and river water samples were usually considerably lower (1.4 to 46 %) than the maximum suspended solids, turbidity, phenolics, iron, zinc and bacteria (94 to 138 %). For many sample pairs, the results were identical or very similar (Appendix, Table A-5), indicating that laboratory analytical variability was very low. The higher variability for some parameters was due either to some samples with parameter concentrations near or below the respective minimum reportable values (e.g., phenolics, iron, zinc), which were assigned a value of zero for statistical calculations, or to the influence of particulates on the results of particulate-associated analytes (e.g., turbidity, bacteria, trace metals). The field blank results (Appendix, Table A-6) show that most of the field data for conductivity, chloride, turbidity, suspended solids, ammonia, total Kjeldahl nitrogen, total phosphorus, iron, and bacteria are above the distilled water "background".

The coefficients of variation range for most analytical parameters in two pairs of blind duplicate (split) sediment samples were usually quite low (0 to 67 %) and similar to the available laboratory CVs (Appendix, Table A-7), indicating that the local within-station sediment heterogeneity was relatively low. The maximum CV of 116 % was for fecal *Streptococcus* is in part due to the approximate nature of the results).

5.2.1 *Effluent Quality*

Densities of bacteria in the WWTP final effluent varied greatly, both between different survey days as well as within days (Table 1). For example, fecal coliforms ranged from 2,300 organisms.dl^{-1} (organisms per 100 ml) to 75,000.dl^{-1} during June 27, 1989, and reached a peak of 1,040,000 organisms. dl^{-1} at 14:00 hours on August 22. Densities of *Escherichia coli* and *Pseudomonas aeruginosa* varied along with those of fecal coliforms (Table 1). Although the data set for *E. coli* is incomplete, this bacterium accounted for 42% to 85% of the fecal coliforms in the final effluent.

Conductivity, pH, chloride, ammonium and phenolics levels in the WWTP discharge changed relatively little during each sampling period, although all but ammonium were noticeably lower in the second survey (Table 1). Overall, turbidity and concentrations of suspended solids, total Kjeldahl nitrogen, total phosphorus, iron and zinc varied somewhat more, with ranges of 5.7 to 19.0 FTU, 18.2 to 45.3 mg.l^{-1}, 18.0 to 31.8 mg.l^{-1}, 0.60 to 2.42 mg.l^{-1}, 680 to 1200 µg.l^{-1} and 16 to 60 µg.l^{-1}, respectively (Table 1). Concentrations of phosphorus in one of three samples on June 29 and two of three samples on August 22 exceeded the 1 mg.l^{-1} (monthly average) GLWQA objective for WWTP discharges to the upper Great Lakes (IJC, 1988).

5.2.2 *Effluent Loadings*

The calculated loadings of bacteria and contaminants in Table 3 represent an important measure of the potential impact of the East End WWTP discharge on waters of the St. Marys River. Mean daily loadings were greatest for all parameters on August 22 (Fig. 8), reflecting the high discharge rate and the elevated concentrations in the effluent (Table 1). For example, relative to the lowest mean daily loading on August 24th, loadings on August 22nd were over 200 times

Table 3. East End WWTP final effluent loadings.

Sampling time Date	Time	Discharge Rate $10^3 m^3.day^{-1}$	Suspended Solids $kg.day^{-1}$	Chloride $kg.day^{-1}$	Fecal coliforms 10^9 org.day^{-1}	*Escherichia coli* 10^9 org.day^{-1}	*Pseudomonas aeruginosa* 10^9 org.day^{-1}	Ammonium $kg.day^{-1}$	Kjeldahl Nitrogen $kg.day^{-1}$	Phosphorus $kg.day^{-1}$	Phenolics $kg.day^{-1}$	Iron $kg.day^{-1}$	Zinc $kg.day^{-1}$
June 27	0.434	38.5	808.5	3364.9	28875	20020	570	596.7	693.0	23.1	1.6	46.2	1.2
	0.4757	40.0	828.0	3648.0	920	680	<8	628.0	728.0	26.4	1.6	36.8	1.6
	0.5243	40.0	760.0	3632.0	20000	13200	~13	808.0	924.0	25.6	1.9	28.4	1.3
	mean	39.5	797.9	3547.1	8101	5644	~31	671.5	775.4	24.9	1.7	36.4	1.3
June 28	--	38.0	771.4	3317.4	29260	155800	114	649.8	748.6	31.9	1.8	45.6	1.9
	--	30.0	576.0	2763.0	1590	1200	~35	534.0	627.0	25.2	1.4	24.9	1.0
	--	30.0	639.0	2649.0	1800	1080	~98	654.0	756.0	27.3	1.7	24.0	0.9
	mean	32.5	656.5	2899.0	4393	2905	~73	610.7	708.8	27.9	1.6	30.1	1.2
June 29	0.3958	37.0	1095.2	3185.7	814	340	~11	606.8	791.8	37.7	1.9	31.4	2.2
	0.4375	30.0	642.0	2658.0	39600	16500	1380	486.0	594.0	24.0	1.5	--	1.4
	0.4792	31.0	564.2	2796.2	4030	2790	899	533.2	632.4	19.8	1.4	21.1	1.3
	mean	32.5	734.5	2869.1	5061	2501	~240	539.2	666.9	26.0	1.6	24.7	1.6
Aug. 22	0.4583	36.0	759.6	2707.2	25920	--	317	712.8	849.6	28.1	1.4	27.7	0.8
	0.5208	**60.0**	1920.0	4290.0	342000	--	1980	1494.0	1908.0	78.0	--	72.0	2.2
	0.5833	48.0	2174.4	3192.0	499200	--	3648	1075.2	1464.0	116.2	2.4	57.6	3.0
	mean	47.0	1471.1	3336.1	164252	--	1318	1046.7	1334.3	63.5	2.0	48.6	1.7
Aug. 23	0.375	30.0	738.0	2040.0	1410	--	66	591.0	747.0	25.5	1.4	26.4	0.7
	0.4167	37.0	1172.9	2671.4	16650	--	244	740.0	906.5	27.7	1.7	37.0	0.8
	0.4583	37.0	969.4	2741.7	2035	--	170	706.7	913.9	24.1	1.6	29.2	0.6
	mean	34.5	941.9	2463.0	3628	--	140	676.2	852.2	25.9	1.5	30.6	0.7
Aug. 24	0.375	30.0	945.0	2025.0	420	300	~6	564.0	717.0	27.0	1.3	23.1	0.7
	0.4167	35.0	885.5	2485.5	1505	910	318	637.0	780.5	26.6	1.3	25.6	0.9
	0.4583	37.0	695.6	2423.5	740	574	212	680.8	834.4	22.2	1.3	26.6	0.8
	mean	33.9	833.9	2308.8	777	539	~38	625.8	776.6	25.1	1.3	25.1	0.8
Study Mean		36.3	873.6	2869.7	6610	2168	~125	678.9	828.6	30.1	1.6	31.7	1.2

NOTES:
"mean" = geometric (log_{10}) mean.
"--"= information or data not available (sample spoiled in laboratory accident).
"<" less than.
"~" approximately.
Bolded discharge rate exceeds the design capacity.

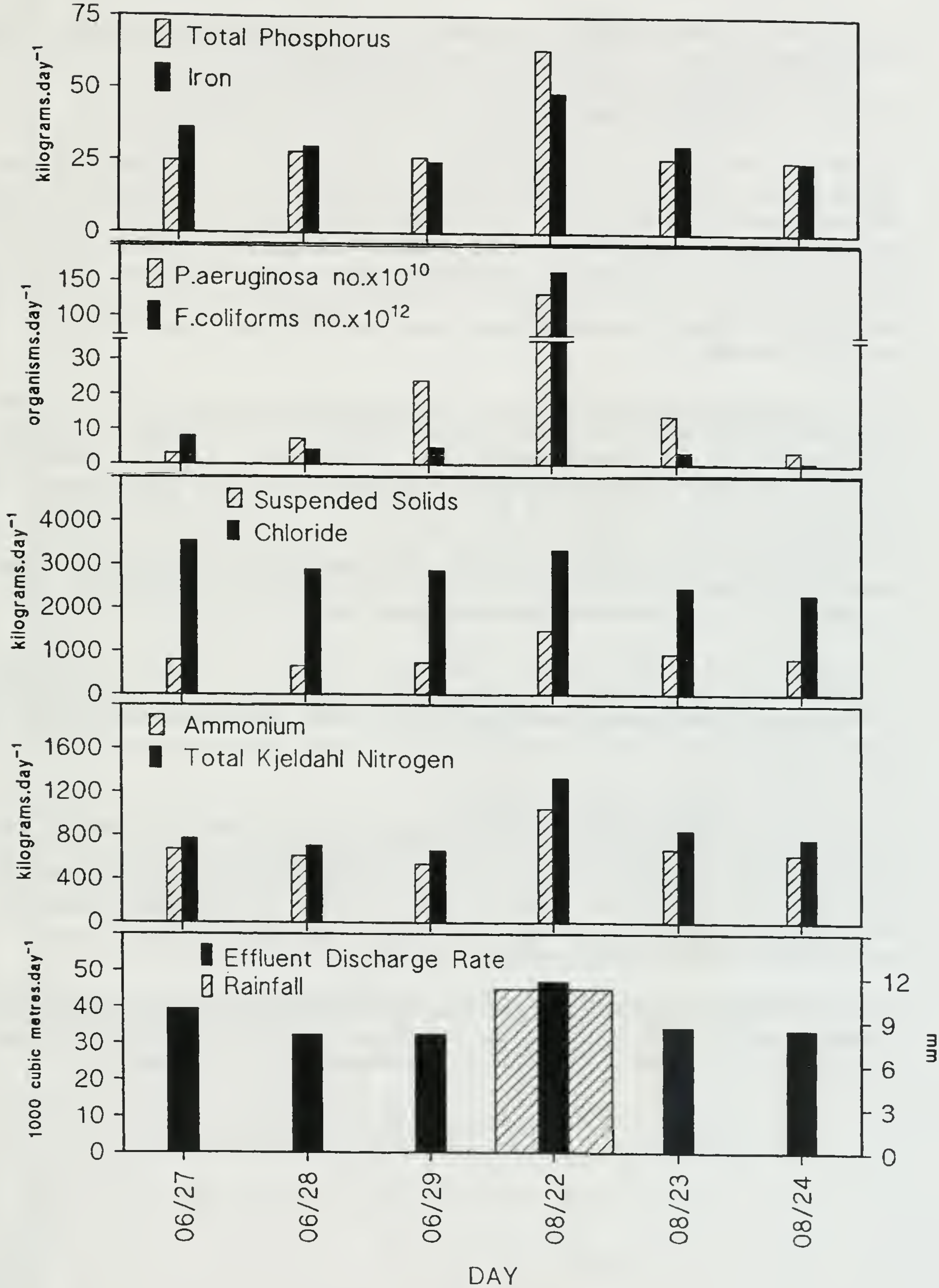

Figure 8. East End WWTP daily average discharge rates and loadings of selected contaminants.

greater for fecal coliform bacteria, and about two times greater for suspended solids, ammonia, total Kjeldahl nitrogen, total phosphorus, iron and zinc (Table 3).

5.2.3 River Water Quality

The WWTP effluent loadings (Table 3) had a noticeable effect on water quality in the Lake George Channel, not only immediately below the discharge at Transect C (Station 34), but also for some distance downstream. This impact was reflected both by concentrations as well as by exceedences of Provincial (PWQO) and Great Lakes Water Quality Agreement (GLWQA) objectives (Table 4). Fecal coliform, *Escherichia coli* and *Pseudomonas aeruginosa* bacteria, conductivity, chloride, ammonia nitrogen, total Kjeldahl nitrogen, phosphorus, phenolics, iron and zinc levels increased noticeably downstream of the WWTP discharge during both surveys (see Figs. 9 through 12).

The most pronounced effect on bacterial levels was found on August 22 and 23 during, and immediately following, a period of heavy rainfall and high effluent loadings (see Sections 5.1.1, 5.2.2, and Table 3). For example, densities of fecal coliform and *E. coli* bacteria reached a peak of 19,000 organisms.dl^{-1} and 16,000 organisms.dl^{-1}, respectively, at 100 m downstream of the effluent discharge pipe on August 22. Faecal coliform densities exceeded the PWQO of 100 organisms.dl^{-1} for the protection of recreational users for as far as Transect L (station 54) at Bell Point, some 4.7 km downstream (Fig. 12). A similar but less extensive trend was also evident for densities of *Pseudomonas aeroginosa*, with exceedences of the PWQO of 20 organisms.dl^{-1} largely confined in downstream extent to 0.9 km at Transect F (Table 4).

Total phosphorus concentrations ranged from 33 $\mu g.l^{-1}$ to 108 $\mu g.l^{-1}$ immediately downstream of the WWTP discharge and these levels all exceeded the PWQO of 30 $\mu g.l^{-1}$ for the prevention of excessive plant growth in rivers and streams (OMOE, 1984). Occasional samples from both the June and August surveys also exceeded the PWQO as up to 0.9 km downstream of the WWTP (Figs. 10 and 12).

The un-ionized ammonia PWQO of 20 $\mu g.l^{-1}$ for the protection of aquatic life was only exceeded on one day, immediately downstream of the WWTP discharge (26 $\mu g.l^{-1}$ on August 24). Only two samples, taken on June 27 and on August 22, contained iron levels above the PWQ and GLWQA objective of 300 $\mu g.l^{-1}$ for the protection of aquatic life. These concentrations, 1,200 and 2,000 $\mu g.l^{-1}$, respectively, correlated with noticeably elevated suspended solids concentrations in the water samples (Table 4 and Fig. 11).

The 1 $\mu g.l^{-1}$ PWQO for phenols to prevent tainting of edible fish flesh was frequently exceeded in samples collected from both upstream and downstream of the WWTP discharge. This indicates the presence and impact of upstream sources, in addition to the WWTP discharge.

Table 4. **Summary of Lake George Channel water quality data.**

Station					Parameter															
Transect (Station Number)	Distance in metres from WWTP outfalls	Distance in metres from CDN. shore	Sample Depth metres	Sampling Date	Temperature °C	pH	Turbidity FTU	Susp.Solids mg.l⁻¹	Fecal coliforms org.dl⁻¹	*Escherichia coli* org.dl⁻¹	*Pseud. aeruginosa* org.dl⁻¹	Conductivity µs cm⁻¹ @25°C	Chloride mg.l⁻¹	Ammonia N µg.l⁻¹	Un-ionized Ammonia µg.l⁻¹	Total Kjeldahl N µg.l⁻¹	Total Phosphorus µg.l⁻¹	Phenolics µg.l⁻¹	Iron µg.l⁻¹	Zinc µg.l⁻¹
B(170)	100	100	0.5	June 28	9.4	7.83	0.87	4.7	~17	~9	<3	95.0	0.58<T	21	0.2	190	9<T	0.8<T	190	1.8<T
"	"	150	0.5	June 27	--	7.85	1.22	2.2<T	~7	~9	<2	96.0	1.60	38	--	170	6<T	0.5<T	90<T	0.9<T
"	"	"	"	June 29	--	7.98	0.80	1.8<T	<7	<7	3	96.0	1.60	21	--	145	2<T	1.4	74<T	0.8<T
"	"	"	"	Aug. 22	16.9	9.03	1.29	3.5	44	40	6	96.0	1.30	36	9	170	7<T	2.2	67<T	0.5<W
"	"	"	"	Aug. 23	17.4	8.13	0.99	2.5<T	46	36	5	97.0	1.50	36	1	160	3<T	1.7	46<T	0.5<W
"	"	"	"	Aug. 24	16.4	7.97	0.66	3.1	52	20	6	97.0	1.60	44	1	170	5<T	5.5	65<T	0.5<W
"	"	"	1.0	Aug. 22	--	7.95	1.47	1.7<T	88	76	4	97.0	1.30	36	--	160	4<T	1.6	78<T	0.7<T
"	"	500	0.5	Aug. 23	16.5	8.01	1.25	1.7<T	16	12	4	96.0	1.30	22	1	130	2<T	1.6	29<T	0.5<W
"	"	"	"	Aug. 24	--	8.01	0.84	1.6<T	4	4	<2	96.0	1.40	22	--	130	4<T	--	29<T	0.5<W
"	"	"	1.0	June 28	9.4	7.96	0.86	0.5<W	4	4	<3	94.0	1.30	7<T	<0.1	140	5<T	0.9<T	44<T	0.5<W
"	"	"	"	June 29	--	7.86	0.74	1.9<T	<4	<4	6	95.0	1.50	2<T	--	130	2<T	1.2	43<T	0.5<W
"	"	"	1.5	June 27	--	7.84	1.02	0.1<T	20	20	2	95.0	1.40	18	--	140	6<T	0.6<T	44<T	0.6<T
"	"	"	"	Aug. 22	16.6	8.04	0.82	0.5<W	<4	<4	4	96.0	1.20	28	1	130	4<T	1.6	47<T	2.5<T
"	"	"	3.0	June 28	--	8.02	0.92	1.0<T	8	8	<2	94.0	1.20	6<T	--	140	4<T	0.6<T	57<T	0.5<T
"	"	"	3.5	June 29	--	7.87	0.65	1.4<T	3	3	<2	95.0	1.50	2<T	--	130	2<W	2.0	47<T	5.4
"	"	"	5.5	June 27	--	8.00	0.94	0.5<W	4	4	<2	95.0	1.30	26	--	140	5<T	0.6<T	37<T	0.5<W
"	"	"	"	Aug. 22	16.7	8.05	1.13	1.2<T	8	8	2	96.0	1.20	20	1	130	5<T	1.6	47<T	0.5<W
C (34)	100	150	0.5	June 27	--	7.56	1.73	1.3<T	>3000	>3000	222	124.0	4.80	758	--	1140	59	0.6<T	97<T	2.9
"	"	"	"	June 29	--	7.98	1.52	2.5	176	84	56	105.0	6.00	802	--	1080	33	1.8	80<T	1.6<T
"	"	"	"	Aug. 22	17.0	7.71	2.20	4.9	19000	16000	320	112.0	3.10	614	6	1010	61	3.0	130	2.5<T
"	"	200	0.5	Aug. 23	17.8	7.65	1.35	4.4	3200	1800	12	142.0	7.40	1900	20	2970	55	8.6	110	1.9<T
"	"	"	"	Aug. 24	16.4	7.36	2.34	4.2	115	~60	<9	173.0	10.92	2683	26	3404	108	9.7	73<T	0.9<T
D (171)	360	140	0.5	June 29	--	7.90	2.20	3.2	<4	<4	2	96.0	1.50	24	--	160	6<T	1.6	100<T	1.3<T
"	"	"	"	Aug. 22	16.7	7.79	11.20	37.2	1560	980	<2	99.0	1.70	32	1	610	61	1.6	2000	21.0
"	"	150	0.5	Aug. 23	17.0	7.88	3.90	2.5	348	184	10	99.0	1.70	80	2	260	16	2.2	210	1.8<T
"	"	"	"	Aug. 24	15.9	7.88	2.00	3.2	28	20	4	99.0	1.70	32	1	180	10	6.8	110	1.0<T
"	"	160	0.5	June 27	--	7.84	1.94	1.9<T	4	4	<2	96.0	1.40	37	--	200	10	0.9<T	100<T	1.1<T
"	"	"	"	June 29	--	7.87	2.00	3.2	2400	320	150	164.0	10.50	1730	--	2030	64	4.6	130	5.3
"	"	"	"	Aug. 22	16.9	7.86	2.81	4.0	1160	787	11	98.0	1.55	60	2	230	14	3.1	174	1.9<T
"	"	180	0.5	June 29	--	7.64	2.84	2.9	102	40	25	109.0	4.60	569	--	699	38	1.7	103	2.5<T
"	"	"	"	Aug. 22	16.8	7.67	2.30	3.0	2640	2260	8	131.0	5.60	1470	14	1830	40	4.2	130	2.1<T
"	"	225	0.5	Aug. 23	17.3	7.98	1.55	3.2	52	28	4	98.0	1.70	80	2	230	8<T	1.2	98<T	1.6<T
"	"	"	"	Aug. 24	15.9	7.72	1.47	2.4<T	48	16	2	106.0	2.50	342	3	540	19	4.4	99<T	1.7<T
"	"	"	1.5	Aug. 23	17.3	7.97	3.70	4.7	148	112	22	99.0	1.80	80	3	250	13	1.6	130	2.3<T
"	"	300	1.0	Aug. 23	17.2	7.88	2.30	4.1	140	80	12	103.0	2.20	198	6	380	16	--	120	1.4<T
"	"	"	"	Aug. 24	16.6	7.81	1.27	2.9	44	24	6	111.0	3.15	543	17	740	26	9.9	91<T	0.8<T
"	"	"	3.0	Aug. 23	16.9	7.93	2.20	5.2	168	120	2	98.0	1.70	76	2	260	14	2.8	150	2.1<T

Station: Transect (Station Number)	Station: Distance in metres from WWTP outfalls	Station: Distance in metres from CDN. shore	Sample Depth metres	Sampling Date	Temperature °C	pH	Turbidity FTU	Susp.Solids $mg.l^{-1}$	Fecal coliforms $org.dl^{-1}$	*Escherichia coli* $org.dl^{-1}$	*Pseud. aeruginosa* $org.dl^{-1}$	Conductivity $\mu s.cm^{-1}$ @25°C	Chloride $mg.l^{-1}$	Ammonia N $\mu g.l^{-1}$	Un-ionized Ammonia $\mu g.l^{-1}$	Total Kjeldahl N $\mu g.l^{-1}$	Total Phosphorus $\mu g.l^{-1}$	Phenolics $\mu g.l^{-1}$	Iron $\mu g.l^{-1}$	Zinc $\mu g.l^{-1}$
E (172)	500	100	0.5	June 28	10.8	7.92	4	2.6	<4	<4	2	97	1.7	34	0.5	270	27	1	280	3.7
"	"	160	0.5	June 27	--	7.88	1.7	2.5	4	4	<2	103	2.12	155	--	493	18	1	135	1.8<T
"	"	"	"	June 29	--	8.04	1.21	0.3<T	<4	<4	3	96	1.6	14	--	165	3<T	0.6<T	62<T	0.7<T
"	"	"	"	Aug 22	16.6	7.89	1.90	3.6	849	540	9	97.0	1.50	56	2	220	12	1.4	134	1.6<T
"	"	180	0.5	June 29	--	7.98	1.19	1.5<T	10	10	<2	96.0	1.50	16	--	160	4<T	1.2	67<T	0.7<T
"	"	"	"	Aug. 22	16.9	7.86	3.40	8.0	192	148	14	97.0	1.50	78	2	250	17	4.6	220	3.4
"	"	"	1.0	June 27	--	7.60	2.50	3.5	68	44	2	118.0	4.10	588	--	950	37	1.6	170	2.2
"	"	200	0.5	June 28	10.8	7.81	3.37	5.6	<6	<4	<2	98.0	1.80	15	0.2	552	40	1.3	222	2.8
"	"	"	"	June 29	--	7.95	1.24	1.7<T	<4	<4	2	96.0	1.60	22	--	160	4<T	1.5	74<T	0.8<T
"	"	"	"	Aug. 22	17.0	7.88	3.40	7.2	164	128	4	97.0	1.60	74	2	270	17	2.0	250	3.5
"	"	"	"	Aug. 23	16.8	7.93	2.80	2.8	128	84	11	99.0	1.60	84	3	240	13	1.6	125	1.9<T
"	"	200	0.5	Aug. 24	16.2	7.95	1.16	2.0<T	49	28	5	98.5	1.70	75	2	220	9<T	8.9	67<T	1.1<T
"	"	"	1.0	June 27	--	7.88	4.80	10.9	32	16	<2	110.0	3.10	414	--	790	36	1.0	1200	12.0
"	"	220	0.5	June 29	--	7.97	1.59	2.1<T	<4	<4	<2	96.0	1.80	34	--	190	5<T	0.6<T	85<T	1.1<T
"	"	"	"	Aug. 22	17.0	7.90	2.10	7.2	212	136	8	98.0	1.50	80	2	260	16	1.0	180	2.9
"	"	"	1.0	June 27	--	7.60	2.60	4.8	72	24	2	112.0	3.50	496	--	730	34	1.6	190	2.8
"	"	240	0.5	June 27	--	7.59	1.51	2.9	20	12	2	111.0	2.60	308	--	580	23	1.6	130	1.6<T
"	"	"	"	June 29	--	7.53	2.10	4.2	104	80	<2	147.0	7.40	1220	--	1660	55	4.6	170	4.4
"	"	"	"	Aug 22	17.0	7.91	3.10	6.9	132	116	6	97.0	1.50	68	2	280	18	2.0	190	2.8
"	"	250	0.5	Aug. 23	16.9	7.98	2.40	1.8<T	104	56	28	98.0	1.60	72	0.5	230	10	2.0	110	1.8<T
"	"	"	"	Aug. 24	16.3	7.90	4.40	4.9	52	48	<2	98.0	1.60	70	1	220	11	1.8	160	1.9<T
"	"	300	0.5	Aug. 23	16.9	7.97	2.30	1.9<T	44	28	20	99.0	1.60	84	1	250	10	2.2	85<T	1.5<T
"	"	"	1.0	June 28	--	7.95	1.59	1.2<T	<7	<4	<2	99.0	1.90	39	--	305	24	1.0	175	2.0<T
"	"	"	"	Aug. 24	16.4	7.94	1.33	3.4	46	26	<4	98.0	1.60	70	2	205	9<T	7.4	175	1.9<T
"	"	"	4.0	Aug. 24	16.6	7.96	1.23	3.5	52	40	2	98.0	1.60	68	1	210	7<T	1.6	110	1.1<T
"	"	350	1.0	Aug. 23	16.9	8.04	1.25	0.5<W	52	36	8	97.0	1.50	38	0.4	180	5<T	1.8	55<T	0.7<T
"	"	"	"	Aug 24	16.4	7.86	1.08	3.4	40	32	10	99.0	1.70	140	4	290	10	16.2	120	1.3<T
"	"	"	4.0	Aug. 23	16.7	8.01	1.10	1.1<T	92	60	6	97.0	1.60	40	1	180	6<T	1.8	69<T	0.8<T
"	"	400	2.0	Aug. 23	16.8	8.04	1.15	0.3<W	72	32	14	97.0	1.40	36	1	160	4<T	2.2	56<T	0.5<W
"	"	"	"	Aug. 24	16.7	7.98	1.45	2.3<T	24	16	2	96.0	1.40	38	1	150	4<T	1.8	70<T	0.8<T
"	"	"	8.0	Aug. 23	16.7	8.04	1.15	0.4<W	68	48	10	97.0	1.40	36	1	150	4<T	2.2	86<T	0.6<T
F (173)	900	150	0.5	June 29	--	7.49	6.50	26.9	68	52	6	109.0	3.20	208	--	2200	145	1.0	84<T	1.7<T
"	"	"	"	Aug. 22	16.9	7.93	1.00	4.7	128	80	6	97.0	1.50	68	2	260	17	1.8	200	2.3<T
"	"	"	"	Aug. 23	16.7	7.99	2.70	1.8<T	96	56	8	98.0	1.60	68	2	210	2<T	1.6	94<T	1.1<T
"	"	"	"	Aug. 24	16.3	7.88	1.34	3.9	92	68	4	97.0	1.70	66	2	210	9<T	15.0	130	1.5<T
"	"	"	0.8	June 27	--	7.87	1.55	0.9<T	20	7	3	105.0	3.20	245	--	570	27	1.3	115	1.6<T
"	"	175	0.5	June 29	--	7.74	1.26	3.0	49	46	<2	105.0	3.10	237	--	320	15	1.5	82<T	2.3<T
"	"	"	"	Aug. 22	16.8	7.95	1.22	6.8	920	560	18	98.0	1.50	80	2	230	10	1.6	140	2.6
"	"	"	1.0	June 27	--	7.76	1.80	6.0	48	24	4	111.0	3.60	334	--	590	28	3.2	130	2.3<T
"	"	200	0.5	June 29	--	7.88	1.42	1.6<T	12	12	<2	97.0	1.80	36	--	200	8<T	0.4<T	98<T	1.0<T
"	"	"	"	Aug. 22	16.8	7.96	1.08	3.1	887	588	33	98.0	1.50	71	2	238	9<T	2.0	105	1.3<T
"	"	"	"	Aug. 23	16.7	7.96	1.47	1.3<T	110	61	9	99.0	1.70	102	3	245	9<T	1.4	79<T	1.4<T
"	"	"	"	Aug. 24	16.3	7.92	1.91	5.3	128	60	2	98.0	1.70	76	2	250	12	14.0	120	1.4<T
"	"	"	1.0	June 27	--	7.91	2	1.6<T	36	4	4	107	3.1	256	--	530	24	2	140	1.5<T

Station					Parameter															
Transect (Station Number)	Distance in metres from WWTP outfalls	Distance in metres from CDN. shore	Sample Depth metres	Sampling Date	Temperature °C	pH	Turbidity FTU	Susp.Solids mg.l⁻¹	Fecal coliforms org dl⁻¹	*Escherichia coli* org.dl⁻¹	*Pseud. aeruginosa* org.dl⁻¹	Conductivity µs.cm⁻¹ @25°C	Chloride mg.l⁻¹	Ammonia N µg l⁻¹	Un-ionized Ammonia µg.l⁻¹	Total Kjeldahl N µg.l⁻¹	Total Phosphorus µg.l⁻¹	Phenolics µg l⁻¹	Iron µg.l⁻¹	Zinc µg.l⁻¹
F (173)	900	200	1.5	Aug. 22	16.8	7.94	1.28	4.2	1040	880	22	97	1.5	74	2	240	10	1.2	170	2.1<T
"	"	"	"	Aug. 23	16.7	7.96	1.88	3.2	172	116	16	99	1.7	92	3	230	10	2	120	1.5<T
"	"	"	"	Aug. 24	16.3	7.90	0.75	5.4	128	60	2	98.0	1.70	78	2	260	13	5.8	120	1.7<T
"	"	225	0.5	June 29	--	7.71	1.37	2.5<T	12	12	<2	111.0	3.40	418	--	660	30	1	110	2.2<T
"	"	"	"	Aug. 22	16.8	7.89	1.87	3.4	1400	1180	22	99.0	1.60	90	3	240	10	1.2	120	1.0<T
"	"	"	1.3	June 27	--	7.69	1.80	2.9	4	4	<2	104.0	2.20	202	--	420	14	1.4	92<T	1.2<T
"	"	"	2.0	Aug. 22	16.8	7.94	1.37	3.6	1060	740	18	98.0	1.50	80	2	230	11	1.6	150	1.5<T
"	"	250	0.5	June 29	--	7.60	1.83	3.0	16	11	<2	104.0	2.85	248	--	512	24	2	124	2.1<T
"	"	"	"	Aug. 22	16.8	7.90	1.06	3.9	1210	880	12	98.0	1.60	87	3	255	12	1.7	145	1.4<T
"	"	"	"	Aug. 24	16.1	7.94	1.14	3.5	67	51	4	99.0	1.70	93	3	240	9<T	10.7	107	1.2<T
"	"	"	0.8	June 27	-	7.94	1.29	1.0<T	13	13	2	103.0	2.44	210	--	429	12	1.2	82<T	1.0<T
"	"	"	1.0	Aug 23	16.9	7.99	1.98	2.0<T	91	76	14	99.0	1.65	89	3	230	9<T	2.9	93<T	1.3<T
"	"	"	2.5	Aug. 22	--	7.93	2.10	5.3	840	680	8	98.0	1.60	80	--	280	13	1 0	180	1.6<T
"	"	"	"	Aug. 24	16.3	7.87	2.40	4.0	84	40	6	99.0	1.70	98	2	260	10	9.2	310	2.3<T
"	"	"	3.0	Aug. 23	16.7	7.96	1.50	2.9	100	56	12	99	1.70	104	3	260	10	2.6	95<T	1.0<T
"	"	"	3.2	June 27	--	7.77	0.76	1.7<T	<4	<4	<2	96.0	1.40	36	--	180	7<T	0.8<T	67<T	0.9<T
"	"	300	1.0	Aug. 23	17.0	7.96	1.90	1.8<T	92	80	12	99.0	1.60	90	3	240	8<T	2.6	68<T	0.7<T
"	"	"	"	Aug. 24	16.1	7.91	1.35	2.6	48	24	4	98.0	1.70	84	3	230	8<T	11.6	140	1.3<T
"	"	"	4.5	Aug. 23	16.7	7.94	2.30	4.3	96	68	8	99.0	1.60	94	3	260	12	2.2	120	1.8<T
"	"	350	2.0	Aug. 23	16.8	8.03	1.20	0.6<T	56	44	8	96.0	1.30	42	1	160	6<T	--	66<T	0.7<T
"	"	"	"	Aug. 24	16.5	7.92	0.96	3.0	36	36	2	97.0	1.50	48	1	180	6<T	1.8	65<T	0.7<T
"	"	"	8.0	Aug. 24	16.6	7.91	1.04	3.3	20	12	2	97.0	1.50	50	2	180	5<T	3.6	96<T	1 0<T
"	"	"	9.0	Aug 23	16.6	8.04	1.05	0.3<W	44	32	10	96.0	1.30	26	1	150	6<T	2.0	49<T	0.5<W
"	"	500	2.0	June 27	--	7.98	0.92	1.4<T	--	--	--	95.0	1.10	16	--	150	5<T	1.0	44<T	0.6<T
"	"	"	"	June 29	--	7.91	0.95	1.1<T	4	4	12	95.0	1.40	6<T	<0.1	130	3<T	0 6<T	33<T	0.5<T
"	"	"	"	Aug. 22	16.7	8.01	1.29	1.5<T	8	8	4	95.0	1.30	18	1	140	4<T	1.6	41<T	0.6<T
"	"	"	"	Aug. 23	16.7	8.04	1.00	0.5<T	20	20	2	96.0	1 20	24	1	140	4<T	1.6	31<T	0.5<W
"	"	"	"	Aug. 24	16.5	7.96	0.84	2.1<T	8	8	2	96.0	1.40	28	1	150	4<T	13.0	49<T	1.3<T
H (174)	1700	100	0.5	Aug. 22	16.7	7.91	0.38	3.7	196	100	32	97.0	1.40	60	2	200	8<T	3.8	110	1.3<T
"	"	"	1.0	Aug. 23	16.4	8.02	1.38	2.6	64	52	2	97.0	1.40	48	1	180	5<T	1.2	70<T	0.8<T
"	"	"	"	Aug. 24	15.8	7.88	1.18	4.3	92	64	12	98.0	1.60	58	2	200	8<T	12.2	93<T	0.8<T
"	"	"	1 5	June 29	--	7.95	1.42	1.6<T	20	20	4	98.0	1.60	34	--	170	2<T	0.6<T	53<T	0.9<T
"	"	"	2.5	June 27	--	7.93	1.05	0.5<T	5	5	<2	96.0	1.40	41	--	190	8<T	0.4<T	63<T	0.8<T
"	"	"	"	Aug. 22	16.7	7.95	1.42	3.7	132	104	16	97.0	1.50	64	2	220	8<T	1.4	130	1.5<T
"	"	"	3.0	Aug 24	16.3	7.90	1.15	4.1	96	52	6	98.0	1.60	22	1	200	9<T	1.8	140	2.2<T
"	"	"	4.0	Aug. 23	16.5	7.99	1.98	3.7	72	52	5	97.0	1.40	48	1	208	9<T	1.9	105	1.1<T
"	"	"	5.0	June 29	--	7.94	0.97	1.8<T	48	36	2	98.0	1.80	62	--	200	2<T	1.0	79<T	1 6<T
"	"	"	10.5	June 27	--	7.81	0.90	0.3<W	4	<4	2	96.0	1.20	34	--	160	8<T	0.8<T	63<T	0.5<W
"	"	200	2.5	June 27	--	7.78	1.00	0.6<T	8	8	2	95.0	0.90<T	18	--	150	5<T	0.2<T	44<T	0.5<T
"	"	"	"	June 29	10.2	7.96	0.92	1 1<T	8	8	4	95.0	1.40	8<T	0.1	120	2<T	0.2<T	38<T	0.8<T
"	"	"	3.0	Aug. 22	16.7	8.00	1.03	2.4<T	268	180	8	97.0	1.30	38	1	150	4<T	1 0<T	78<T	0.7<T
"	"	"	"	Aug. 23	16.6	8.04	0.95	0.4<W	28	24	<2	96.0	1.30	24	1	140	3<T	1.6	40<T	0.5<W
"	"	"	3.0	Aug. 24	16.4	7.97	0.77	2.4<T	56	32	4	97.0	1.40	60	2	150	3<T	1.6	38<T	0.9<T

Station					Parameter															
Transect (Station Number)	Distance in metres from WWTP outfalls	Distance in metres from CDN. shore	Sample Depth metres	Sampling Date	Temperature °C	pH	Turbidity FTU	Susp.Solids $mg.l^{-1}$	Fecal coliforms $org.dl^{-1}$	*Escherichia coli* $org.dl^{-1}$	*Pseud. aeruginosa* $org.dl^{-1}$	Conductivity $\mu s.cm^{-1}$ @25°C	Chloride $mg.l^{-1}$	Ammonia N $\mu g.l^{-1}$	Un-ionized Ammonia $\mu g.l^{-1}$	Total Kjeldahl N $\mu g.l^{-1}$	Total Phosphorus $\mu g.l^{-1}$	Phenolics $\mu g.l^{-1}$	Iron $\mu g.l^{-1}$	Zinc $\mu g.l^{-1}$
H (174)	1700	200	9.5	June 27	--	7.77	1.10	1.4<T	8	4	2	95.0	1.00	18	--	200	8<T	0.6<T	46<T	0.5<W
"	"	"	10.0	June 29	--	7.93	0.99	1.2<T	16	12	<2	95.0	1.40	10	--	120	2<T	0 2<T	38<T	0.8<T
"	"	"	12.0	Aug 22	16.6	8.03	1.19	2.3<T	28	24	10	96.0	1.30	26	1	140	3<T	1.6	60<T	1.6<T
"	"	"	"	Aug. 23	16.5	8.05	1.13	1.5<T	44	24	4	96.0	1.30	24	1	140	4<T	1.6	46<T	0.5<W
"	"	"	"	Aug. 24	16.8	7.95	1.00	2.6	28	24	<2	96.0	1.40	30	1	160	4<T	1.8	51<T	0.5<W
"	"	300	2.0	June 27	--	7.77	1.20	1.7<T	<4	<4	2	95.0	1.00	18	--	200	8<T	1.0	47<T	0.7<T
		"	"	June 29	10.4	7.85	0.91	1.1<T	13	11	<2	95.0	1.40	12	0.1	140	2<T	0.2<T	37<T	0.7<T
"	"	"	"	Aug 22	16.7	8.00	1.15	1.4<T	12	12	4	96.0	1.20	22	1	140	5<T	1.2	55<T	0.5<W
"	"	"	"	Aug. 23	16.6	8.02	1.02	1.1<T	<4	<4	4	96.0	1.30	26	1	150	4<T	1.6	54<T	0.5<W
"	"	"	"	Aug. 24	16.5	7.94	0.74	2 0<T	20	16	<2	97.0	1.40	30	1	150	4<T	2 2	55<T	0.5<W
"	"	"	7.0	June 27	--	7.76	1.20	2.9	<4	<4	<2	95.0	1.10	42	--	160	7<T	1.2	56<T	0 6<T
"	"	"	"	June 29	10.0	7.92	0.77	0.4<W	10	<3	4	95.0	1.40	10	0.1	120	2<T	0 2<T	40<T	0.6<T
"	"	"	8.0	Aug. 23	16.5	8.03	1.64	2.2<T	16	12	8	96.0	1.40	26	1	150	4<T	1.6	80<T	0.6<T
"	"	"	"	Aug. 24	16.5	7.95	0.81	2.2<T	28	28	<2	96.0	1.40	22	1	140	4<T	17.8	48<T	0.5<W
"	"	"	9.0	Aug. 22	16.6	7.98	0.72	2.5<T	16	16	8	96 0	1.20	20	1	140	6<T	1.2	130	0.8<T
"	"	400	1.0	June 29	10.8	7.84	0.87	0.7<T	<4	<4	<2	95.0	1 40	12	0.1	150	2<T	0 6<T	50<T	0.6<T
"	"	"	"	Aug. 22	16.8	8.00	1.15	3 2	20	16	2	96.0	1.20	22	1	140	4<T	1.8	73<T	0.5<W
"	"	"	"	Aug. 23	16.6	8.01	0.68	0.6<T	40	40	<2	96 0	1.40	26	1	140	4<T	1.4	38<T	0.5<W
"	"	"	"	Aug. 24	16.6	7.94	0.70	1.5<T	32	24	2	96.0	1 40	20	1	140	4<T	7.4	30<T	0.5<W
"	"	"	1.5	June 27	--	7.85	0.90	1.3<T	8	8	<2	95.0	1.60	18	--	150	6<T	0.6<T	46<T	0.9<T
L (54)	4700	280	2.5	June 27	--	7.91	1.30	0.8<T	20	20	4	96.0	1.10	26	--	180	8<T	0 8<T	50<T	1.2<T
"	"	320	1.0	Aug. 22	17.0	7.92	0.74	2.3<T	492	332	12	97.0	1.45	41	1	160	6<T	1.6	76<T	0.8<T
"	"	"	"	Aug. 23	16.6	7.92	1.63	2.6	296	228	14	97.0	1.50	64	2	200	11	1.4	77<T	0.9<T
"	"	"	"	Aug. 24	16.6	7.81	1.04	2.7	44	24	2	98.0	1.60	58	2	210	7<T	15.0	63<T	0.5<W
"	"	"	5.0	Aug. 23	16.5	7.97	1.88	3.7	272	220	8	98.0	1 50	62	2	220	9<T	1.2	140	1.2<T
"	"	400	1.5	Aug. 24	16.4	7.83	1.29	3.4	156	96	4	98.0	1.60	52	2	200	7<T	1.8	81<T	0.6<T
"	"	"	2.0	Aug. 22	17.0	7.96	1.08	2.6	780	428	<2	97.0	1.40	40	1	160	6<T	0 8<T	74<T	0.8<T
"	"	"	"	Aug. 23	16.4	7.99	2.00	2.6	196	152	32	98.0	1.50	62	2	200	7<T	1.6	81<T	1.0<T
"	"	"	5.0	June 27	-	7.93	0.90	0.3<W	24	16	<2	95.0	1.10	32	--	170	6<T	0.6<T	54<T	0.6<T
"	"	"	8.0	Aug. 23	16.5	7.98	1.49	3.7	140	116	16	98.0	1.50	58	2	190	12	1.0	140	1.2<T
"	"	650	1.5	Aug. 23	16.5	8.03	0.80	0.5<T	60	44	4	96.0	1.30	28	1	140	3<T	1 0<T	36<T	0.5<W
"	"	"	"	Aug. 24	16.5	7.94	0.72	2.6	44	28	4	96.0	1.40	22	1	150	4<T	7.6	39<T	0.5<W
"	"	"	3.5	Aug. 22	16.8	8.00	1.20	2.5	36	36	8	96.0	1.30	24	1	130	4<T	1.2	70<T	0.5<W
"	"	"	4.5	June 27	--	7.94	1.00	1.1<T	17	4	<2	95.0	1.20	20	--	160	8<T	0.6<T	48<T	0.9<T
"	"	"	6.5	Aug. 23	16.5	8.03	1.15	2.0<T	38	28	8	96.0	1.30	28	1	155	5<T	1.1<T	68<T	0.5<W
Minimum Reportable Value					--	0.00	0.05	0.3	--	--	--	1.0	0.20	2	--	20	2	0.2	10	0.5
PWQ Objective/Guideline					--	>6.5-<8.5	--	--	(100)	100	--	--	--	--	20	--	30	1	300	30
GLWQA Objective					--	<6.5-<9.0	--	--	–	–	–	–	–	–	–	–	–	–	300	30

NOTES: upstr. = upstream; downstr.= downstream
"--" = not available; "~" approximately "<"= less than; ">"= greater than
"<T" = a measurable trace amount; interpret with caution; "<W"= no measurable response (zero); less than reported value
Underlined values in shaded cells exceed PWQ (OMOE, 1984) or GLWQA (IJC, 1988) objective or guideline.

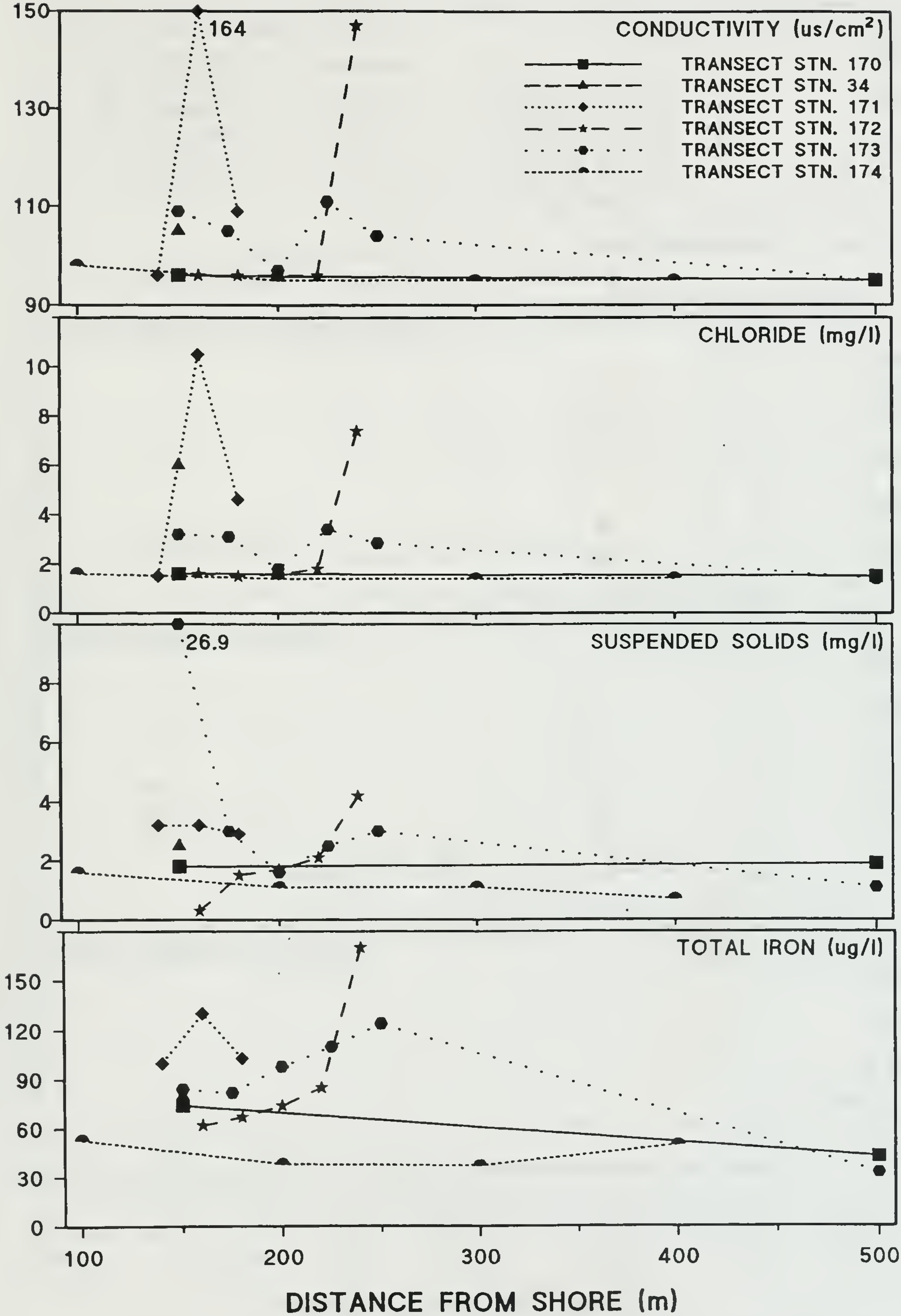

Figure 9. Cross-sectional distribution of conductivity, chloride, suspended solids and iron in Lake George Channel surface waters on June 29, 1989.

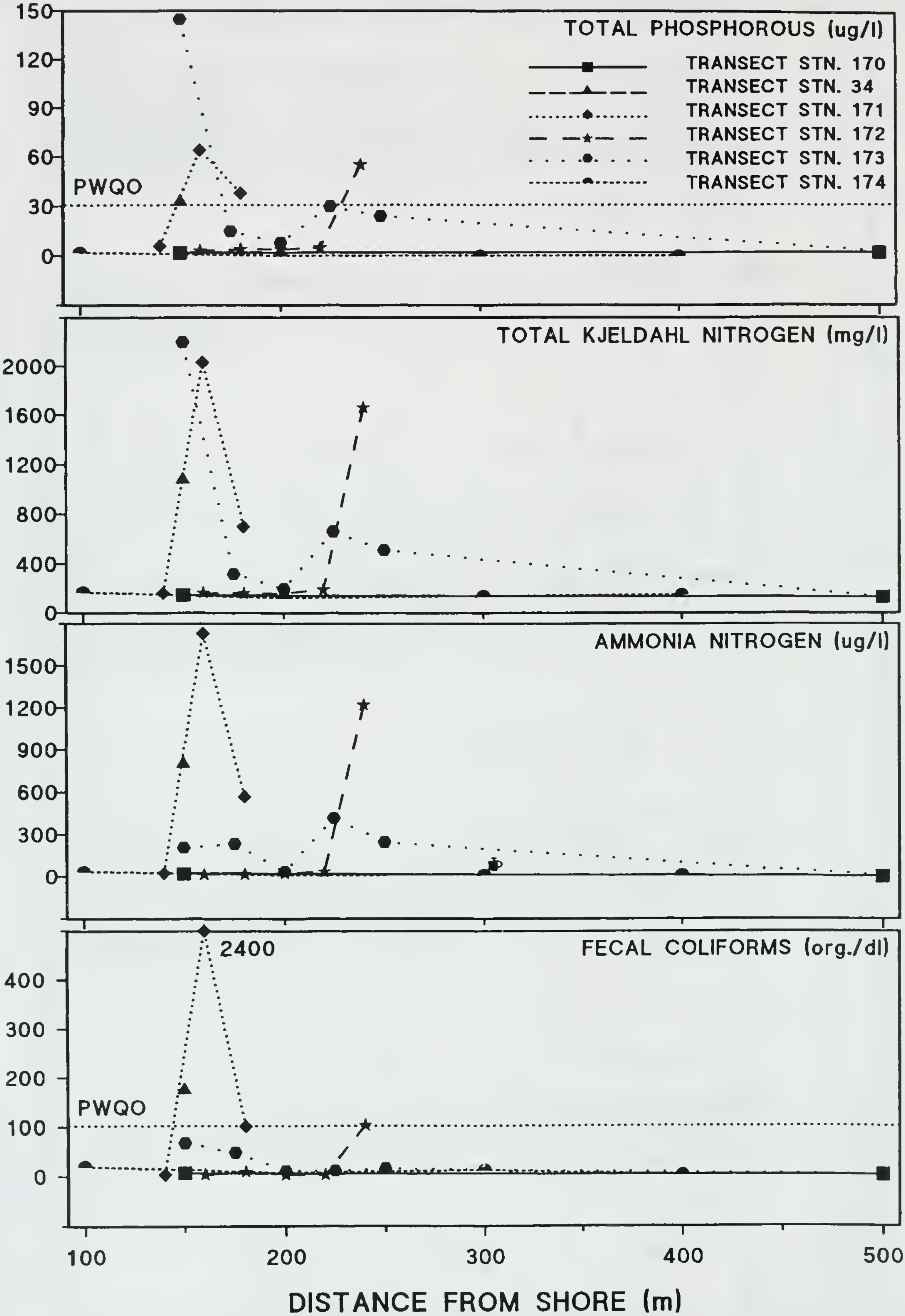

Figure 10. Cross-sectional distribution of total phosphorus, total Kjeldahl nitrogen, ammonia nitrogen and fecal coliform bacteria in Lake George Channel surface waters on June 29, 1989.

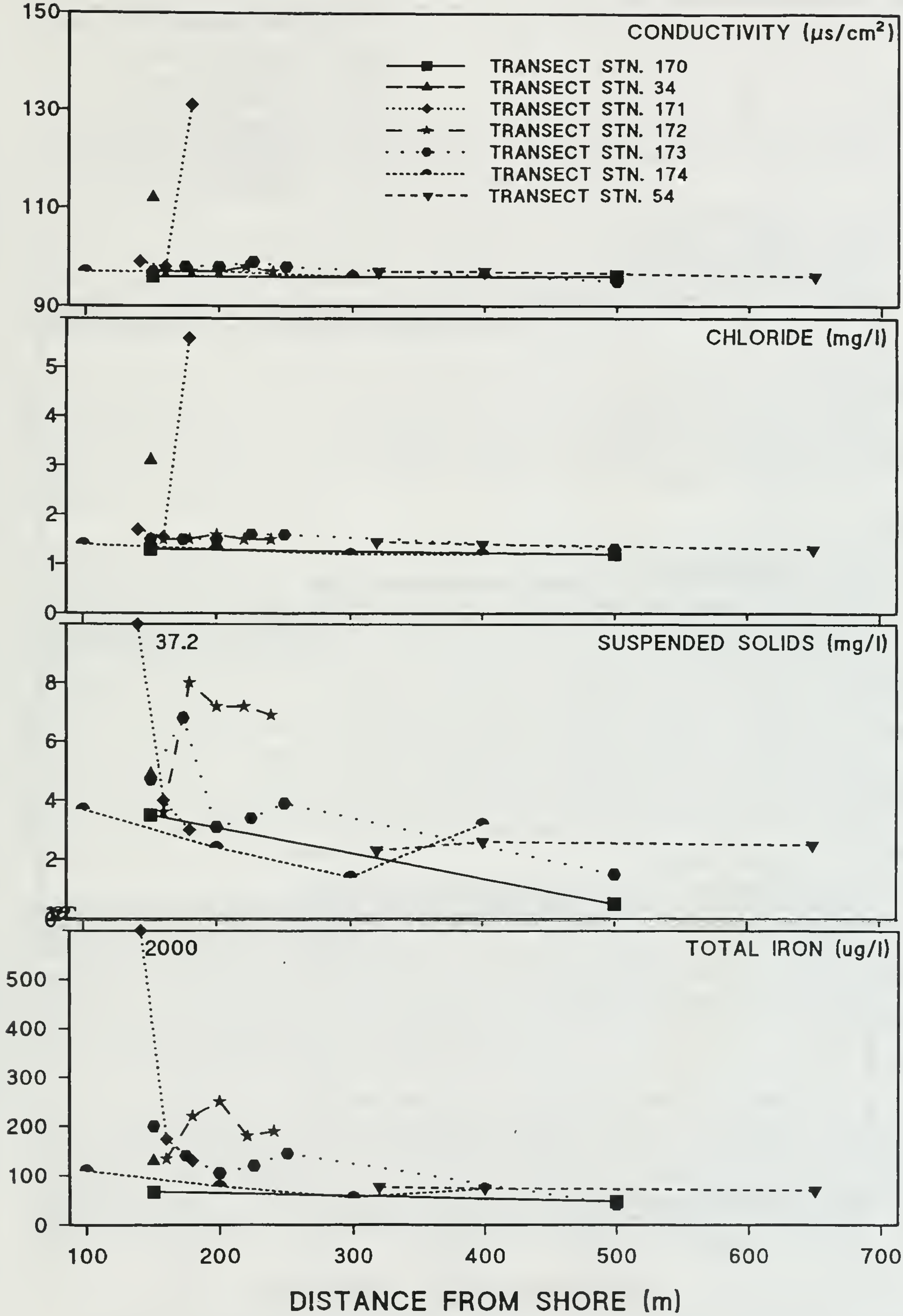

Figure 11. Cross-sectional distribution of conductivity, chloride, suspended solids and iron in Lake George Channel surface waters on August 22, 1989.

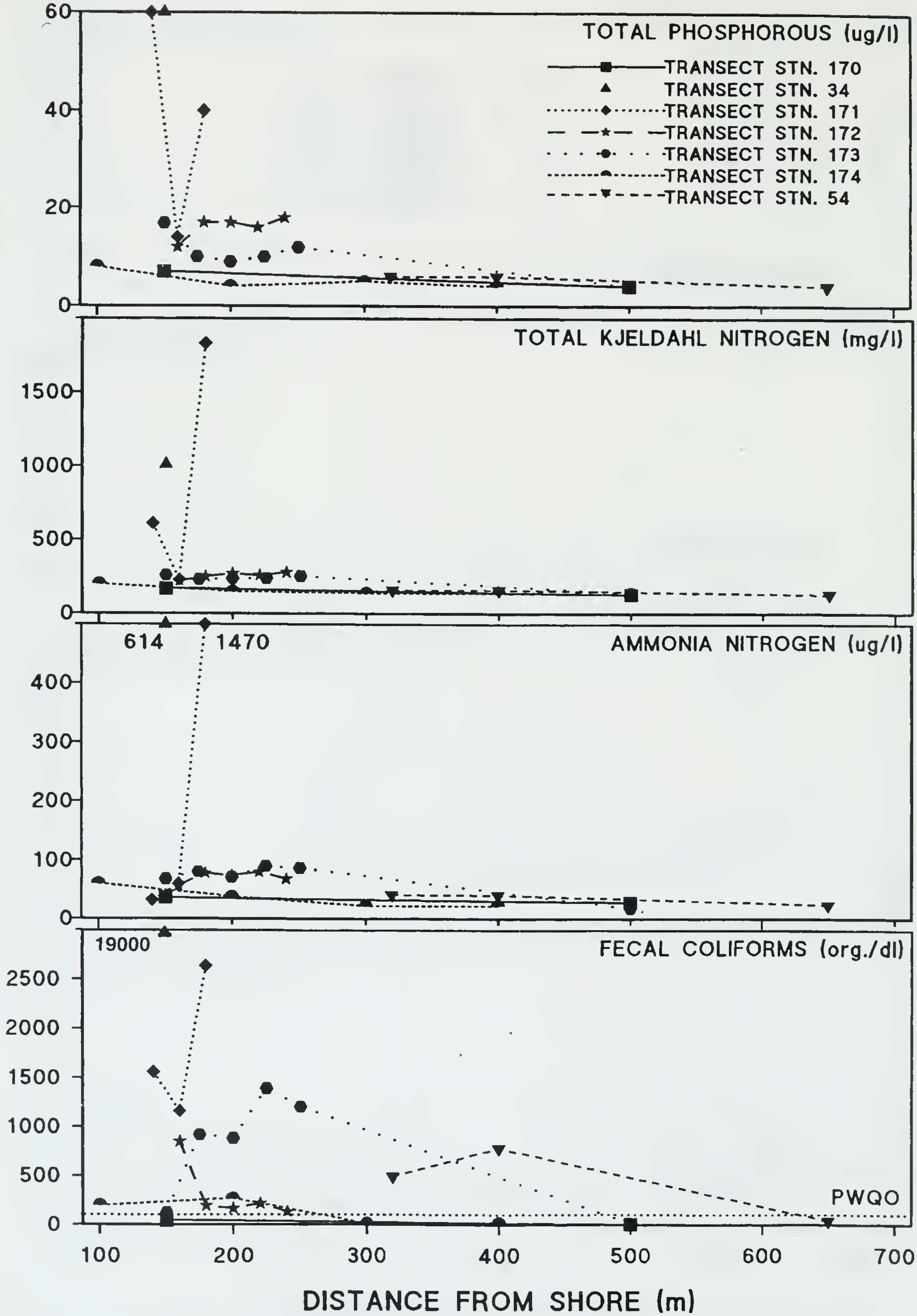

Figure 12. **Cross-sectional distribution of total phosphorus, total Kjeldahl nitrogen, ammonia nitrogen and fecal coliform bacteria in Lake George Channel surface waters on August 22, 1989.**

5.2.4 *Surficial Sediment Quality*

Visual descriptions indicate that surficial (upper 3 cm) sediments collected in the Lake George Channel and in Little Lake George were generally very organic in nature (i.e., "oozy"), often with a sewage or oily odour. All samples had an oily sheen (Table 5).

Particle size distribution analysis showed that sediments at a high proportion of the stations were of a sandy-silt or silty-sand composition, and sediments from the inshore stations in the Lake George Channel usually had more than 50% of their particle size distribution in the silt-clay (<62 μm diameter) fraction. Samples from further offshore, where the current is somewhat greater, often had somewhat less silt-clay content (Table 5; Fig. 13).

Analysis of samples for bacteria was complicated by the need for dilution, and this raised the detection limits for organisms. In general, however, sediments from up to 2 km downstream of the WWTP discharge (as far as Transect I/Station 176) contained elevated densities (relative to Transect B) of fecal coliform, *E. coli* and faecal *Streptococcus* bacteria. Densities of these organisms reached as high as about 134,000, 14,400 and 21,000 organisms per kg of wet sediment, respectively (Table 6).

Concentrations of nutrients and persistent inorganic contaminants (e.g., heavy metals) usually increased downstream of the WWTP discharge (compare stations on Transects C and E in Table 7 and Figs. 13 and 14). Also, concentrations were often higher at inshore stations than at offshore stations. Correlation analysis (Appendix Table A-9) indicated that concentrations of arsenic, cyanide, heavy metals and many of the individual PAH compounds correlated significantly ($p < 0.05$) with one another $r = 0.50$ to 1.0), suggesting a common (i.e., upstream) source. Sediment moisture content and loss on ignition (LOI) also correlated significantly with many of these contaminants. In contrast, the proportion of silt and clay (i.e., "fines") in sediments or of TOC content correlated significantly with only a few of the persistent contaminants (arsenic, cyanide, cadmium) and with total Kjeldahl nitrogen or total phosphorus. Solvent extractable (oils and greases) levels only correlated significantly with TOC content. Consequently, concentrations of the persistent contaminants plotted in Figures 13 and 14 were not normalized to TOC or percent fines.

Concentrations of many of the contaminants exceeded sediment quality guidelines for the protection of benthic organisms (Persaud *et al.*, 1993) at a number of the sampling locations. Stations with a large number of parameters exceeding these guidelines included those on Transects C, E, F, G, H, L (Stations 34, 172, 173, 175, 174 and 54) in Lake George Channel and Station 87 in Little Lake George, as well as the upstream reference, Transect B (Station 170). This indicates that upstream sources contribute or have contributed to sediment quality problems in the Lake George Channel and in Little Lake George.

Some of the samples from the stations noted in the previous paragraph also contained concentrations exceeding the Provincial Sediment Quality Guidelines "Lowest Effect Level" (LEL) for arsenic (6 $mg.kg^{-1}$, or ppm), cadmium (0.60 $mg.kg^{-1}$), chromium (26 $mg.kg^{-1}$), copper (16 $mg.kg^{-1}$), iron (20,000 $mg.kg^{-1}$), lead (31 $mg.kg^{-1}$), manganese (460 $mg.kg^{-1}$), mercury (0.2 $mg.kg^{-1}$), nickel (16 $mg.kg^{-1}$) and zinc (120 $mg.kg^{-1}$). In addition, concentrations of available cyanide at these stations exceeded the Provincial guideline of 0.1 $mg.kg^{-1}$ for Open Water

Table 5. Characteristics of Lake George Channel and Little Lake George surficial sediments.

Station		Visual & Olfactory Description					Particle Size Distribution				
Transect (Number)	Metres from Canadian shore	Type	Plants?	Detritus?	Oily?	Odour	Coarse Sand (2000-1000 μm) %	Sand (999-63 μm) %	Silt & Clay (< 62 μm) %	Moisture %	Density g.cm^{3}
B (170)	150	ooze	√		√ (very)	sewage	0.10	74.60	25.18	38.0	1.521
	500	ooze	√		√	faint	0.30	15.00	84.17	78.0	1.433
C (34)	150	ooze over sandy layer				slight sewage	0.20	70.90	28.71	43.0	1.457
E (172)	150	ooze over sandy layer	√	√	√ (very)	slight sewage	0.10	44.27	55.35	42.3	1.283 ± 0.050
	300	black ooze		√	√ (very)	oily	0.30	69.25	30.35	62.0	1.264 ± 0.015
F (173)	100	ooze over red-brown layer	√		√ (very)		0.10	37.30	62.20	63.0	1.253
	300	ooze over some sand		√	√ (very)	slight	0.40	78.00	21.43	39.0	1.509
G (175)	50	black ooze	√	√	√ (very)	moderate sewage	0.10	31.20	65.40	66.0	1.238 ± 0.006
	150	ooze	√ (*Cladophora*)	√	√	oily	0.50	60.90	39.10	60.0	1.309
-- (177)	20	silty sand & ooze		√ (wood fibre)	√		0.40	46.50	52.71	45.0	1.400
-- (178)	0	ooze & sandy gravel	√ (*Cladophora*)		√	oily	2.30	51.90	45.55	30.0	1.577
H (174)	50	black ooze		√	√ (very)	slight	0 10	41 40	58.50	61.0	1.223
	100	ooze & some sand		√	√ (very)	slight	0.17	58.00	41.65	59.7	1.318 ± 0.028
I (176)	10	ooze & sand	√		√ (quite)		0.30	78.60	20.94	32.0	1.574
L (54)	320	black ooze	√	√	√ (very)	oily	0 30	21 60	78 00	74 0	1 143
-- (87)	400	organic ooze		√	√	slightly oily	0.10	31 10	68.58	58.0	1.313
MRV		--	--	--	--	--	0.10	0.10	0.10	--	–

NOTES: "√= present

Table 6. Bacterial densities in Lake George Channel and Little Lake George surficial sediments.

Station		Bacterial Density		
Transect (Number)	Metres from Canadian shore	**Fecal coliforms** number.kg^{-1}	***Escherichia coli*** number.kg^{-1}	**Fecal *Streptococcus*** number.kg^{-1}
B (170)	150	<10000	<10000	<10000
	500	<10000	<10000	<10000
C (34)	150	<10000	<10000	<10000
E (172)	150	<10000	<10000	<10000
	300	~14142	~10000	<100000
F (173)	100	~30000	~20000	<100000
	300	~60000	~20000	<10000
G (175)	50	~10000	<10000	<100000
	150	~10000	~10000	<100000
-- (177)	20	~10000	<10000	<10000
-- (178)	0	~60000	~60000	<100000
H (174)	50	~30000	<10000	<10000
	100	~133887	~14422	<21544
I (176)	10	~70000	~10000	<10000
L (54)	320	<10000	<10000	<10000
-- (87)	400	<10000	<10000	<10000
Minimum Reportable Value (MRV)		10000	10000	10000

NOTES: "<" = actual result is less than reported value, based on a count of zero for the filter and the particular dilution used (10- or 100-fold).
"~" = approximate value, based on counts between 1 and 9 and the particular dilution used (10- or 100-fold).

Table 7. Concentrations of organic matter, nutrients and inorganic contaminants in Lake George Channel and Little Lake George surficial sediments. All concentrations on dry weight basis.

Station		Organic Matter		Nutrients		Inorganics and Heavy Metals												
Transect (Number)	Metres from CDN shore	LOI	TOC	TP	TKN	Arsenic	Cadmium	Chromium	Copper	Cyanide (avail)	Cyanide (free)	Iron	Lead	Manganese	Magnesium	Mercury	Nickel	Zinc
		g kg^{-1}	g.kg^{-1}	g.kg^{-1}	g.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg kg^{-1}
B (170)	150	21	20	0.22	0.53	4.8	0.99	63	70	0.63	0.010<W	**45000**	62	490	4700	<0.01<W	26	190
"	500	110	77	0.59	4.60	16	0.23<T	19	32	1.7	0.010<W	12000	21	120	1400	0.11	7.4	71
C (34)	150	28	19	0.50	1.00	2.6	0.51	37	37	0.41	0.010<W	24000	57	230	1900	0.33	14	160
E (172)	150	57	41	0.62	2.10	8.42	0.52	38	27	0.739	0.010<W	23513	40	319	3887	0.25	13	140
"	300	100	78	0.96	2.75	11	0.82	63	60	1.018	0.010<W	**46497**	57	525	2600	0.30	21	205
F (173)	100	72	49	1.00	4.00	8.10	0.95	54	51	0.85	0.010<W	32000	58	320	3000	0.32	16	200
"	300	42	40	0.37	0.80	6.50	0.34	29	20	0.13	0.010<W	23000	21	250	1700	0.09	9.3	91
G (175)	50	84	64	0.79	2.45	11.1	1.15	98	65	1.99	0.010<W	**58498**	84	600	3550	0.29	23	285
"	150	94	83	0.60	1.60	8.80	0.74	61	44	0.8	0.010<W	**45000**	36	490	2500	0.12	17	170
-- (177)	20	37	23	0.31	0.99	2.30	0.36	24	14	0.082	0.010<W	8900	20	110	1800	0.09	7.2	68
-- (178)	0	19	14	0.40	0.84	1.60	0.24<T	24	19	0.022<T	0.010<W	12000	15	200	3100	0.02<T	10	54
H (174)	50	110	75	0.82	2.10	11	1.20	88	87	3.2	0.019<T	**61000**	90	700	4200	0.34	27	300
"	100	62	56	0.51	0.90	7.09	0.72	76	50	1.15	0.019<T	**41648**	55	391	2699	0.24	16	172
I (176)	10	24	14	0.25	0.53	2.40	0.31	22	19	0.062	0.010<W	13000	18	150	1600	0.06	7.6	66
L (54)	320	76	5.8	<0.01<W	**4.9**	20	1.80	75	100	2.800	0.019<T	**58000**	160	830	4700	0.24	37	450
-- (87)	400	58	34	0.49	1.80	6.20	0.62	38	36	0.47	0.010<W	21000	36	280	3800	<0.01<W	18	140
MRV		5	0.2	0.02	0.10	0.20	0.05	2	1	0.010	0.010	20	1	--	--	0.01	1	1
Background *		140	66	0.27	0.30	3.2	0.87	14	24	0.022<T	0.010<W	7400	21	94	1800	0.03<T	7.1	40
OWDMDG		60	--	--	--	--	--	--	--	0.1	0.1	--	--	--	--	--	--	--
PSQG-LEL		--	10	0.6	0.55	6	0.6	26	16	--	--	20000	31	460	--	0.2	16	120
PSQG-SEL		--	100	2	4.8	33	10	110	110	--	--	40000	250	1100	--	2	75	820

NOTES: "--" = not available.
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); less than reported value.
"*" = upstream background concentration in Point aux Pins Bay (Kauss, 1999; OMOE 1986-87).
"OWDMDG" = concentration below which disposal of dredged material in open water is permitted (Persaud & Wilkins, 1976).
"PSQG-LEL" = Lowest Effect Level of contamination that can be tolerated by the majority of benthic organisms (Persaud *et al.*, 1993).
"PSQG-SEL" = Severe Effect Level" of contamination at which pronounced disturbance of the benthic community can be expected: TOC-normalized (Persaud *et al.*, 1993)
Underlined values in shaded cells exceed the PSQG-LEL or OWDMDG; bolded values exceed the PSQG-SEL.

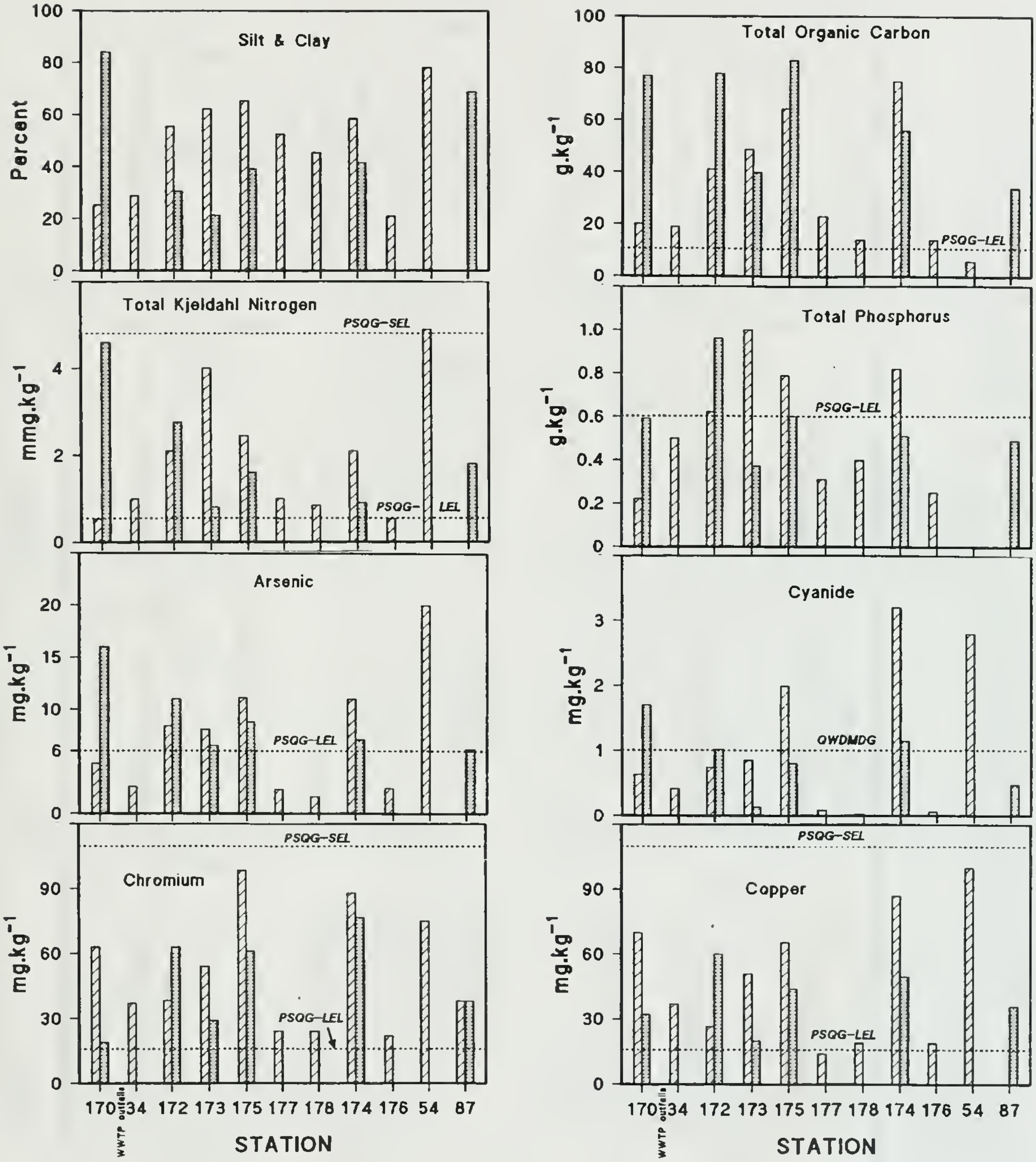

Figure 13. **Silt and clay content and concentrations of total organic carbon, total Kjeldahl nitrogen, total phosphorus, arsenic, cyanide, chromium and copper in Lake George Channel and Little Lake George surficial sediments.** Bars with diagonal lines represent stations closest to shore; shaded bars represent offshore stations.

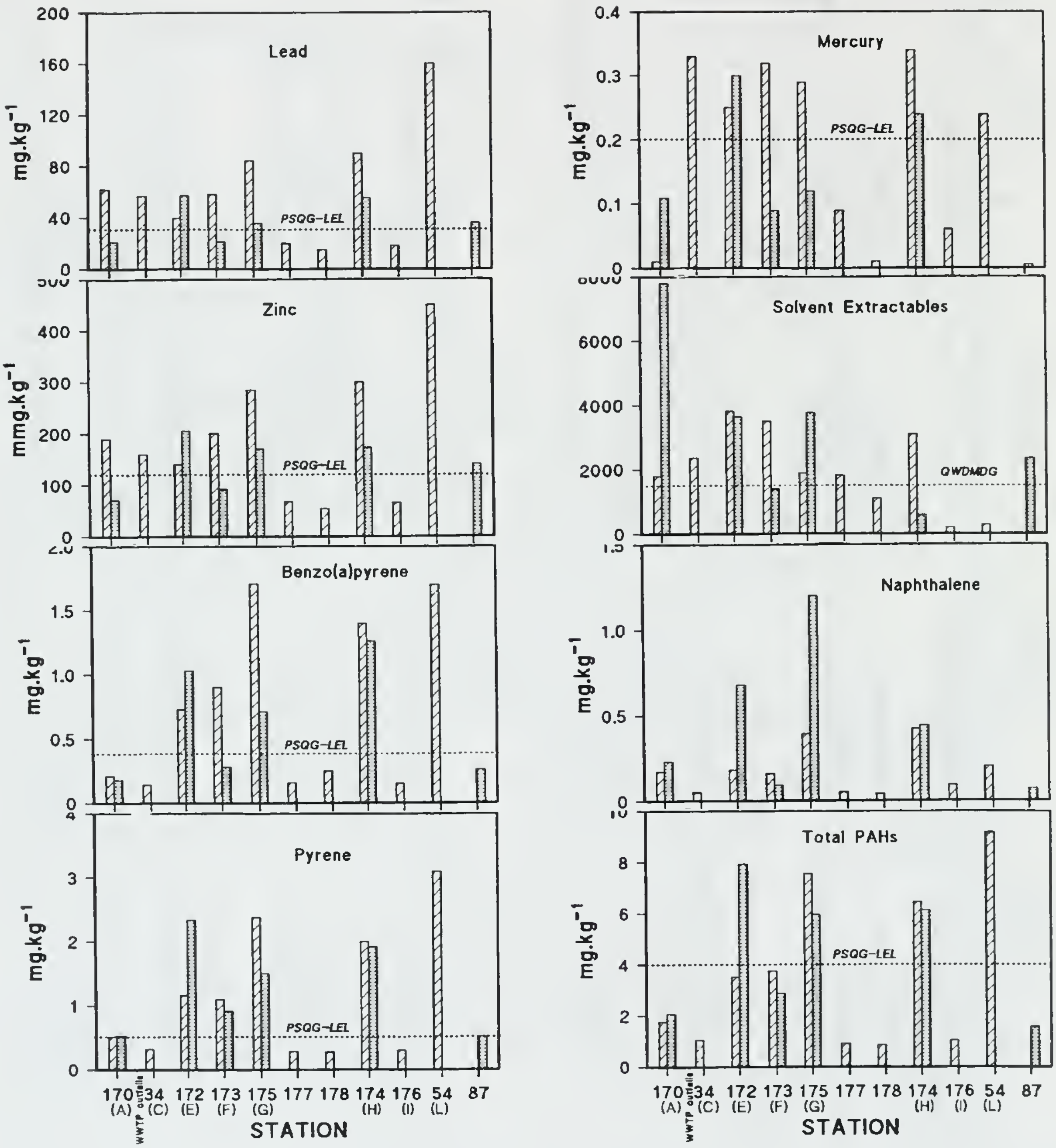

Figure 14. **Concentrations of lead, mercury, zinc, solvent extractables, benzo(a)pyrene, naphthalene, pyrene and Total PAHs in Lake George Channel and Little Lake George surficial sediments.** Bars with diagonal lines represent stations closest to shore; shaded bars represent offshore stations.

Table 8. Concentrations of solvent extractables and polycyclic aromatic hydrocarbons in Lake George Channel and Little Lake George surficial sediments. All concentrations in $mg.kg^{-1}$, dry weight basis.

Station			Polycyclic Aromatic Hydrocarbons																
Transect (Number)	Metres from CDN shore	Solvent Extractables	Acenaph-thene	Acenaph-thylene	Anthra-cene	Benzo(a)-anthracene	Benzo(b)-fluoranthene	Benzo(k)-fluoranthene	Benzo(g,h,i)-perylene	Benzo(a)-pyrene	Chrysene	Dibenzo-(a,h)anthra-cene	Fluoran-thene	Fluorene	Indeno-(1,2,3-cd)pyrene	Naphtha-lene	Phenan-threne	Pyrene	Total of 16 PAHs
B (170)	150	1794	0.04<T	0.05<T	0.08	0.24	0.28	0.11	0.11	0.21	0.31	0.04<T	0.63	0.04<T	0.12	0.17	0.32	0.52	1.76
"	500	7807	0.06	0.05<T	0.09	0.22	0.25	0.12	0.12	0.18	0.30	0.04<T	0.73	0.08	0.13	0.23	0.46	0.53	2.08
C (34)	150	2360	0.04<T	0.05<T	0.06	0.16	0.17	0.10	0.07	0.14	0.21	0.04<T	0.39	0.04<T	0.08	0.05	0.22	0.32	1.06
E (172)	150	3814	0.04<T	0.08	0.12	0.59	1.22	0.39	0.33	0.73	0.96	0.10	1.33	0.06	0.37	0.18	0.47	1.16	3.51
"	300	3636	0.11	0.12	0.39	1.34	1.86	0.78	0.66	1.03	1.59	0.23	2.78	0.14	0.85	0.68	1.30	2.34	7.95
F (173)	100	3506	0.04<T	0.08	0.14	0.69	1.20	0.62	0.62	0.90	1.00	0.21	1.30	0.06	0.70	0.16	0.49	1.10	3.75
"	300	1387	0.05<T	0.05<T	0.18	0.42	0.38	0.16	0.11	0.28	0.51	0.04<T	1.20	0.07	0.12	0.09	0.54	0.91	2.86
G (175)	50	1880	0.05<T	0.18	0.32	1.28	2.20	1.02	0.95	1.71	1.88	0.35	2.68	0.10	1.15	0.39	0.95	2.38	7.55
"	150	3764	0.10	0.11	0.33	0.66	0.91	0.39	0.44	0.71	0.89	0.14	1.80	0.13	0.46	1.20	1.00	1.50	5.96
-- (177)	20	1807	0.04<T	0.05<T	0.02	0.15	0.30	0.13	0.11	0.16	0.26	0.04<T	0.33	0.04<T	0.13	0.05	0.12	0.28	0.91
-- (178)	0	1105	0.04<T	0.05<T	0.03	0.16	0.33	0.19	0.16	0.25	0.28	0.05	0.31	0.04<T	0.18	0.04<T	0.10	0.27	0.86
H (174)	50	3110	0.07	0.15	0.31	1.10	1.70	0.83	0.79	1.40	1.60	0.25	2.20	0.12	0.82	0.42	1.00	2.00	6.44
"	100	578	0.05<T	0.15	0.32	1.11	1.77	0.68	0.60	1.26	1.44	0.23	2.22	0.11	0.66	0.44	0.89	1.92	6.13
I (176)	10	194	0.04<T	0.05<T	0.05	0.15	0.18	0.11	0.09	0.15	0.21	0.04<T	0.37	0.04<T	0.10	0.09	0.17	0.30	1.03
L (54)	320	280	0.10	0.15	0.36	1.50	2.30	1.00	0.89	1.70	2.00	0.30	3.60	0.11	0.96	0.20	1.30	3.10	9.16
-- (87)	400	2340	0.04<T	0.05<T	0.06	0.30	0.38	0.26	0.12	0.26	0.40	0.04<T	0.61	0.04<T	0.13	0.07	0.23	0.52	1.56
MRV		5.0	0.04	0.04	0.05	0.01	0.02	0.06	0.02	0.04	0.04	0.02	0.04	0.02	0.04	0.04	0.04	0.07	--
Background *		1106	0.04<T	0.04<T	0.01<T	0.02<T	0.06<T	0.02<T	0.04<T	0.04<T	0.02<T	0.04<T	0.04	0.04<T	0.04<T	0.04<T	0.07<T	0.06<T	0.62<T
OWDMDG		1500	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PSQG-LEL		--	--	--	0.22	0.32	--	0.24	0.17	0.37	0.34	0.06	0.75	0.19	0.2	--	0.56	0.49	4
PSQG-SEL		--	--	-	370	1480	--	1340	320	1440	460	130	1020	160	320	--	950	850	10000

NOTES: "--" = not available. "<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); less than reported value.
"*" = upstream background concentration in Point aux Pins Bay (Kauss, 1999).
"OWDMDG" = concentration below which disposal of dredged material in open water is permitted (Persaud & Wilkins, 1976).
"PSQG-LEL-= Lowest Effect Level of contamination that can be tolerated by the majority of benthic organisms (Persaud *et al.*, 1993.
"PSQG-SEL" = Severe Effect Level" of contamination at which pronounced disturbance of the benthic community can be expected: Requires TOC-normalization (Persaud *et al.*, 1993.
Underlined values in shaded cells exceed the PSQG-LEL or OWDMDG; bolded values exceed the PSQG-SEL.

Disposal of Dredged Material (Persaud & Wilkins, 1976). Levels of iron from seven of the stations also exceeded the Provincial "Severe Effect Level" (SEL) sediment quality guideline of 40,000 $mg.kg^{-1}$ (Table 7). The LEL and SEL guidelines are, respectively, concentrations below which the majority (95%) of benthic organisms would be protected and above which pronounced disturbance of the benthic community can be expected (Persaud, *et al.*, 1993).

Total phosphorus only exceeded the PSQG-LEL of 0.60 $g.kg^{-1}$ at stations on Transects E, F, G and H, all downstream of the WWTP, but total Kjeldahl nitrogen exceed the PSQG-LEL of 0.55 $g.kg^{-1}$ on all but one transect, and exceeded the PSQG-SEL of 4.80 $g.kg^{-1}$ on transect L (Table 7 and Fig. 13).

Concentrations of solvent extractables exceeded the Provincial Open Water Dredged Material Disposal Guideline of 1,500 $mg.kg^{-1}$ at stations on Transects C, E, F, G and H, and at 177 and 87, as well as at the upstream reference stations on Transect B, which had the highest concentration (Table 8). This is contrary to the other contaminants, and suggests a dominating influence from upstream sources (Fig. 14).

All 16 of the unsubstituted PAH compounds analyzed for were detected at all stations; however, concentrations were usually less than 1 $mg.kg^{-1}$. Compounds with the highest concentrations included fluoranthene, phenanthrene and pyrene (Table 8). Presently there are Provincial Sediment Quality Guidelines for 12 individual PAH compounds and for "Total PAHs'. However, sediments from six of the stations, all downstream of the WWTP discharge, contained total PAH levels that exceeded the Provincial LEL of 4 $mg.kg^{-1}$ (Fig. 14). Concentrations of many of the individual PAH compounds (as well as of total PAHs) were highest at stations on Transects E, F, G, H and L, located downstream of the WWTP discharge, and 11 of these PAHs exceeded their respective PSQG-LELs (Table 8; Fig. 14).

Of the 16 unsubstituted PAHs analyzed for in the present study, fluoranthene, pyrene, benzo(b)fluoranthene and chrysene were, on average, present at the highest concentrations. This pattern (Fig. 14) is quite similar to that reported for sediments collected upstream, in the Algoma Slag Dump nearshore in 1989 (Kauss, 1999).

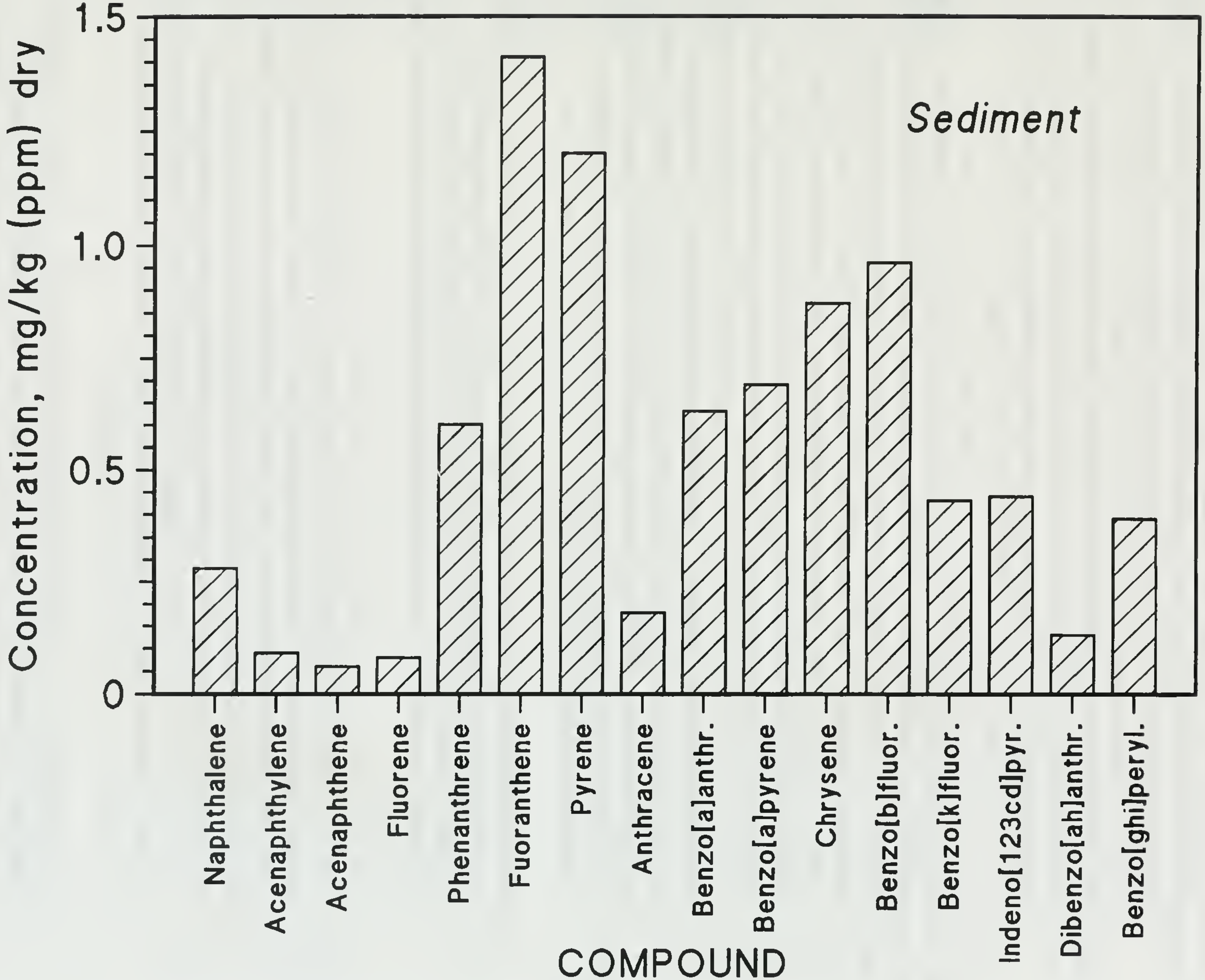

Figure 15. **Average PAH compound profile in sediments**. Compounds are listed order of decreasing water solubility, from left to right (Mackay *et al.*, 1992).

6.0 CONCLUSIONS AND RECOMMENDATIONS

(i) During the June and August 1989 surveys, the East End WWTP design capacity was exceeded once, during a period of high rainfall on August 22nd. WWTP discharge loadings were greatest for all measured parameters (suspended solids, chloride, bacteria (fecal coliforms, *Escherichia coli*, *Pseudomonas aeruginosa)*, ammonium, total Kjeldahl Nitrogen, total phosphorus, phenolics, iron and zinc) on August 22nd, due to the high discharge rate and elevated levels in the final effluent. On this day, estimated loadings of faecal coliforms were up to 200 times greater, while suspended solids, ammonia, total Kjeldahl nitrogen, total phosphorus, iron and zinc loadings were up to two times greater than on the day with the lowest loading.

The impact of the WWTP discharge on Lake George Channel water quality was evident on fecal coliforms, *E. coli*, *Pseudomonas aeruginosa*, conductivity, chloride, ammonia, total Kjeldahl nitrogen, total phosphorus, phenolics, iron and zinc, levels of which increased noticeably downstream of the discharge point during both surveys. The greatest effect on bacteria densities in river water was found on August 22nd and 23rd , during and immediately following the period of heavy rainfall. For example, fecal coliform densities exceeded the PWQO for the protection of recreational users as far as 4.7 km downstream (i.e., at Bell Point). (*E. coli* accounted for 42% to 85% of the fecal coliforms in the final effluent.) Total phosphorus exceeded the PWQO to prevent excessive aquatic plant growth in rivers for a distance of up to 0.9 km downstream of the discharge point. Phenolics concentrations exceed the PWQO to prevent tainting of fish flesh at upstream as well as downstream locations, indicating the influence of sources located upriver of the WWTP.

<u>Recommendation</u>: *Increases in the efficiency of bacterial treatment and contaminants removal should be pursued. Also, the influence of high rainfall events on WWTP discharge quality and loadings should be minimized, either through plant capacity expansion, or temporary containment of storm water runoff until proper treatment can be effected.*

(ii) The discharge area for the WWTP is on a shallow shelf of less than 2 m depth, where currents are quite variable - but typically less than 10 $cm.sec^{-1}$, with variable direction of flow. Because of the shallowness, flow in the discharge area is more susceptible to influence by the wind than the deeper, faster moving waters of the main channel. For example, under northeast wind conditions, the direction of travel of drogues was initially perpendicular to shore, progressing to about 45 degrees relative to the shore for the first 200 m of travel. This can cause the WWTP discharge plume to impinge on U.S. waters (i.e., result in transboundary pollution).

<u>Recommendation</u>: *In conjunction with Recommendation (i), if possible, the discharge point should be moved into deeper, faster moving water to improve the dispersion characteristics and mitigate adverse impacts on nearby waters and surficial sediments.*

In combination, Recommendations (i) and (ii) would also avoid undesirable impacts within the river further downstream, including transboundary pollution.

(iii) Surficial sediments in Lake George Channel and in Little Lake George were generally very organic in nature (i.e., "oozy"), often with a sewage or oily odour. All samples had an oily sheen. Sediments from up to 2 km downstream of the WWTP discharge contained elevated densities of fecal coliform, *Escherichia coli* and fecal *Streptococcus* bacteria. Densities of these organisms reached as high as about 134,000, 14,400 and 21,000 organisms per kg of wet sediment. Concentrations of nutrients and persistent inorganic contaminants (e.g., heavy metals) usually increased downstream of the WWTP discharge, and concentrations were often higher at inshore stations than at offshore stations. Correlation analysis indicated that concentrations of arsenic, cyanide, heavy metals and many of the individual PAH compounds correlated significantly with one another, suggesting a common source. Concentrations of many of the contaminants in Lake George Channel and Little Lake George sediments, as well as at the upstream reference, exceeded the Lowest Effect Level Provincial Sediment Quality Guidelines for the protection of benthic organisms. This indicates that upstream sources contribute or have contributed to sediment quality problems in the Lake George Channel and in Little Lake George. These contaminants include arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc, total PAHs and of 11 individual PAHs. In addition, concentrations of available cyanide at some stations exceeded the Provincial guideline for Open Water Dredged Material Disposal. Iron also exceeded the Provincial "Severe Effect Level" (SEL) sediment quality guideline at some stations. Total phosphorus only exceeded the PSQG-LEL at some stations downstream of the WWTP, but total Kjeldahl nitrogen exceed the PSQG-LEL on all but one transect.

Concentrations of solvent extractables exceeded the Provincial Open Water Dredged Material Disposal Guideline at stations on downstream transects, as well as at the upstream reference stations, which had the highest concentration. This suggests a dominating influence from upstream sources.

<u>Recommendation</u>: *The WWTP discharge was identified as contributing, on average, 31.7 and 1.2 $kg.day^{-1}$ of iron and zinc, respectively. Further monitoring should be conducted on the WWTP final effluent to determine the concentrations and loadings of the persistent contaminants exceeding guidelines in Lake George Channel sediments. Also, the relative contribution of upstream sources and their loadings to sediment contamination in Lake George Channel and Little Lake George should be investigated. This includes point and non-point sources.*

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APPENDIX

Table A-1. 1989 effluent, water and sediment quality sampling station locations.

Station Description						
	Distance (m.) from:					
Transect (Number)	WWTP outfalls, upstream (u/s) or downstream (d/s)	Canadian shore	Water Depth, m	Latitude	Longitude	Remarks
1	0	-150	0.1	46°30'16"	84°15'22"	Sault Ste. Marie, ON East End WWTP final contact chamber
B (170)	100 u/s	150	1			control u/s of Cass Point; on SMD 4.87E (ON)
"	"	500	2.3	46°30'13"	84°15'26"	control u/s of Cass Point; on SMD 4.87E (MI)
C (34)	100 d/s	150	1			immediately d/s of WWTP discharge; on SMD 5.0E
"	"	200	1	46°30'20"	84°15'23"	"
D (171)	360 d/s	140	1			on SMD 5.17E
"	"	150	1.2			"
"	"	160	1.5			"
"	"	180	1.5			"
"	"	225	2			"
"	"	300	4	46°30'27"	84°15'15"	"
E (172)	500 d/s	150	1			on SMD 5.26E
"	"	160	1			"
"	"	180	1.5			"
"	"	200	1.5			"
"	"	220	1.5			"
"	"	240	1.5			"
"	"	250	1.5			"
"	"	300	3			"
"	"	350	5			"
"	"	400	10	46°30'31"	84°15'12"	on SMD 5.26E;; at Brassar Point
F (173)	900 d/s	100	1			on SMD 5.5E
"	"	150	1.1			"
"	"	175	1.5			"
"	"	200	2.1			"
"	"	225	2.5			"
"	"	250	3.2			"
"	"	300	5.7			"
"	"	350	10			"
"	"	500 *	10.6	46°30'44"	84°15'03"	on SMD 5.5E; in Masta Bay
G (175)	1200 d/s	50	4.5	46°30'50"	84°14'56"	off storm sewer; opposite Point Lewis
"	"	150	~ 6.5			"
177	1300 d/s	20	~ 1.5	46°30'54"	84°14'52"	off 51 River Road
178	1330 d/s	· 0	~ 1.5	46°30'55"	84°14'21"	in private boat slip
H (174)	1700 d/s	50	~ 1.5			on SMD 6.0E; near Air-dale Ltd
"	"	100	4			on SMD 6.0E
"	"	200	14			"
"	"	300	10.3			"
"	"	400 *	4.3	46°31'05"	84°14'41"	on SMD 6.0E; d/s of Point Lewis
I (176)	2300 d/s	10	~ 1.5	46°30'54"	84°14'53"	off beach at Partridge Point
L (54)	4700 d/s	320 *	6			on SMD 7.9E; off beach at Bell point
"	"	400 *	9.3			on SMD 7.9E
"	"	650 *	10.1	46°32'27"	84°13'12"	on SMD 7.9E; at Palmers Point
87	6750 d/s	400	1.8	46°32'57"	84°11'31"	in Little Lake George

NOTES. "*" = water sampled at only 0.2 of total depth.
"<" = less than.
"~" = approximately
"SMD" = IJC river range; positions are "fixed" at U.S. shore

Table A-2. Summary of project analytical requests and capabilities, historical survey data and water quality objectives

Parameter	Analytical Method *							Observed Values **		Water Quality Objectives	
	Reporting Units	Method Code	Standard Deviation of: Lab. Controls	Standard Deviation of: Lab. Duplicates	Lab. Blank	Lowest Reportable Value, W	T Value	Background	WWTP Effluent	GLWQA Objective	OMOE PWQ Objective/Guideline
Turbidity	FTU	002A11	0.11	0.056 to 0.241	0.057	0.05	0.25	--	--	--	<10% increase
Suspended Solids	$mg.l^{-1}$	206AB5	0.000021	1.07 to 1.87	0.213	0.5	2.5	1.6<T to 3.5	29.4 to 53.2	--	--
pH	--	003A12	0.041	0.152 to 0.196	--	0	0	--	7.99 to 8.15	6.5 to 9.0	6.5 to 8.5
Conductivity @ 25°C	$\mu mhos.cm^{-1}$	002B12	2.59	0.79 to 1.86	--	1	5	97.6 to 102.4	536 to 688	TDS not >present level	<1/3 TDS increase over present level
Chloride as Cl	$mg.l^{-1}$	004BC2	0.15	0.121 to 0.161	-0.031	0.2	1	1.20 to 1.85	60 to 75	--	--
Total Phosphorus, as P	$mg.l^{-1}$	504BC2	0.024	0.0129 to 0.0491	0.001	0.020	0.100	0.004<T to 0.020<T	2.80 to 5.53	--	0.030
Ammonia, as N	$mg.l^{-1}$	103DC2	0.008	0.003 to 0.018	0.0019	0.002	0.010	0.046 to 0.066	11.6 to 21.0	0.02 (unionized); 0.5 total	0.02 (unionized)
Total Kjeldahl Nitrogen, as N	$mg.l^{-1}$	004AC2	0.013	0.0173 to 0.0326	0.018	0.020	0.100	0.046 to 0.200	15.5 to 30.6	--	--
Phenolics, 4AAP reactive as Phenol	$\mu g.l^{-1}$	002BC2	0.48	0.148 to 0.848	--	0.2	0.1	0.6<T to 1.8	1.8 to 23.6	1	1
Total Iron, as Fe	$mg.l^{-1}$	536BA1	0.134	0.037 to 0.056	0.021	0.003	0.010	<0.050 to 0.110	0.81 to 2.20	0.300	0.300
Total Zinc, as Zn	$mg.l^{-1}$	535BA1	0.034	0.002	0.004	0.001	0.001	<0.001 to 0.003	0.04 to 0.41	0.030	0.030
Faecal Coliforms	$organisms.dl^{-1}$	TF124	--	2.9 to 9.0	--	10	--	10 to 108	900 to $5.1x10^6$	--	100
Escherichia coli	$organisms.dl^{-1}$	TFC24	--	2.6 to 10.1	--	10	--	8 to 68	800 to $4.5x10^6$	--	--
Pseudomonas aeruginosa	$organisms.dl^{-1}$	PF48	--	1.9 to 7.6	--	10	--	9 to 13	20 to $4.7x10^3$	--	--

NOTES
"*" from OMOE (1983 & 1991)
"**" from 1986/87 St. Marys River MISA Pilot Site Study (OMOE, unpubl. data); background = station 440 m upstream of WWTP discharge.
"--" = not available.

Table A-3. Comparison of project analytical requests and capabilities, and historical survey data with sediment quality objectives.

		Analytical Method*						Observed Values**		Sediment Quality Objectives
Parameter	Reporting Units	Method Code	Standard Deviation of: Controls	Standard Deviation of: Duplicates	Blank	Lowest Detectable, W	T Value	Background	Lake George Channel	MOE Dredging Guideline
Fecal Coliform	org.100g^{-1}	FCMMF	NA	NA	NA	1000	NA	NA	230,000-800,000	NA
E. coli	org.100g^{-1}	ECMMF	NA	NA	NA	1000	NA	NA	43,000-240,000	NA
Fecal Streptococcus	org.100g^{-1}	FSMF	NA	NA	NA	1000	NA	NA	NA	NA
Particle Size Distribution (<62 μm)	%	007PZ1	NA	NA	NA	0.1	NA	49	23	NA
Percent Moisture	%	009AB1	NA	NA	NA	NA	NA	55	29-70	NA
Residual Loss on Ignition	mg.g^{-1}	001AI2	3.05	0.85 to 9.47	NA	5.0	NA	68	23-140	60
Total Organic Carbon	mg.g^{-1}	001AI0	NA	NA	NA	5.0	NA	28	20-92	NA
Total Phosphorus	mg.g^{-1}	314CC2	0.03	0.02 to 0.07	4.85	0.02	NA	0.27	0.22-1.2	1.0
Total Kjeldahl Nitrogen	mg.g^{-1}	314CC2	0.06	0.05 to 0.38	NA	0.10	0.10 to 0.20	30	0.80-4.5	2.0
Total Arsenic	μg.g^{-1}	542AF3	1.58	0.14 to 0.38	NA	0.20	NA	NA	NA	8.0
Free Cyanide	μg.g^{-1}	NA	NA	NA	NA	0.01	NA	NA	NA	NA
Available Cyanide	μg.g^{-1}	NA	NA	NA	NA	0.01	NA	NA	NA	NA
Total Cadmium	μg.g^{-1}	535AA0	0.81	0.07 to 0.17	0.05	0.20	NA	0.5	0.35-2.4	1.0
Total Chromium	μg.g^{-1}	535AA0	25.5	1.45 to 2.57	1.60	2.00	NA	9.6	21-110	50
Total Copper	μg.g^{-1}	535AA0	150	1.05 to 3.23	1.26	1.00	NA	NA	NA	25
Total Iron	μg.g^{-1}	535AA0	1,262	437 to 1,857	1.80	20.00	NA	5,400	15,000-81,000	10,000
Total Lead	μg.g^{-1}	535AA0	94.5	1.25 to 14.40	1.33	1.00	NA	24	18-130	50
Total Magnesium	μg.g^{-1}	535AA0	NA	NA	NA	NA	NA	970	1,300-5,400	NA
Total Manganese	μg.g^{-1}	535AA0	38.1	12.88 to 79.90	0.14	2.50	NA	55	130-780	NA
Total Mercury	μg.g^{-1}	541AF1	0.03	0.01 to 0.07	NA	0.01	NA	NA	NA	0.3
Total Nickel	μg.g^{-1}	535AA0	62.6	0.51 to 4.55	0.98	1.00	NA	4.2	7.5-47	NA
Total Zinc	μg.g^{-1}	535AA0	294	5.19 to 17.75	7.32	1.00	NA	24	50-380	100
Solvent Extractables	μg.g^{-1}	X600W0	NA	NA	NA	1	NA	1,260	989-2,152	1,500
Polycyclic Aromatic Hydrocarbons (16 compounds)	μg.g^{-1}	EN100A	NA	NA	NA	0.01 to 0.07	0.01 to 0.07	0.01<T-0.07<T	3.17<T-10.4	NA

* From MOE (1983) and Sturgis (1987)

** St. Marys River MISA Pilot Site Study (1992), background = Point aux Pins Bay; bacteria data from floating material collected in July 1989.

NA = Not Available

Table A-4. Meteorological conditions prior to and during July and August, 1989 surveys.

Date		Rainfall,	at Sault Ste. Marie, ON airport				on survey vessel	
			Wind Speed, $km.h^{-1}$		Wind Direction		Wind	
Month	Day	mm.	Average	Range	Average	Range	$km.h^{-1}$	Direction
June	20	0.0	.5.7	0 - 15	SSE	E - WSW	--	--
"	21	0.0	9.7	0 - 22	ESE	E - SE	--	--
"	22	0.0	10.6	0 - 22	SE	E - SSW	--	--
"	23	13.4	12.0	7 - 22	E	E - SSE	--	--
"	24	trace	17.8	0 - 30	NW	E - NNW	--	--
"	25	0.4	9.4	0 - 22	NW	E - NW	--	--
"	26	0.2	6.3	0 - 20	SW	E - W	--	--
"	27 *	trace	11.0	0 - 24	NW	N - NNW	9 - 18	SW
"	28 *	0.0	19.6	7 - 35	NW	N - NW	14 - 19	NE
"	29 *	0.0	5.6	0 - 17	NW	SE - NW	--	--
"	30 *	0.0	7.3	0 - 19	E	E - SW	--	--
July	1 *	0.0	6.2	0 - 15	E	E - WSW	--	--
August	15	1.6	19.3	7 - 28	NW	W - NNW	--	--
"	16	0.0	16.9	0 - 28	NW	N - NWW	--	--
"	17	0.0	6.5	0 - 15	W	ENE - NNW	--	--
"	18	0.0	7.5	0 - 15	SSE	ENE - S	--	--
"	19	0..0	9.5	6 - 15	ESE	E - S	--	--
"	20	0.6	12.0	4 - 28	NW	E - NNW	--	--
"	21	trace	17.1	0 - 32	WNW	N - NNW	--	--
"	22 *	11.2	9.6	0 - 26	E	N - NNW	0 - 32	ESE
	23 *	0.0	10.7	0 - 24	WNW	N - NNW	9 - 28	NNE
	24 *	0.0	11.0	0 - 22	ENE	N - NNW	9 - 19	NE

NOTES: Airport weather data courtesy of Environment canada, Atmosheric Environment Service.
" * " = survey day.
" – " = data not available.

Table A-5. River water sample field blind duplicate (split) data.

		Station:	WWTP effluent				Station 170		Station 34		Station 171							
		Date:	Jun 28		Aug 24		Jun 28		Aug 24		Jun 27		Jun 29		Aug 22		Aug 24	
		m. from shore:	0		0		100		200		180		180		180		300	
Parameter	Units	Sample No.:	25007	25008	83799	83800	83841	83842	88521	88522	83808	83809	83877	83878	88431	88432	88519	88520
Conductivity	$\mu s.cm^{-1}$		785.0	788.0	822.0	823.0	85	85	180.0	187.0	88.0	88.0	118.0	100.0	88.0	88.0	111.0	111.0
Chloride	$mg.l^{-1}$		88.20	88.40	89.80	81.20	0.20<W	150	11.70	10.20	1.40	1.40	4.80	4.40	1.80	1.50	3.30	3.10
pH	$-log_{10}[H^+]$		7.98	7.87	7.45	7.48	7.79	7.87	7.35	7.38	7.83	7.85	7.85	7.83	7.85	7.88	7.78	7.83
Turbidity	FTU		11.20	11.80	8.50	8.10	1.80	0.43	2.50	2.20	2.10	1.80	1.22	8.80	2.40	3.30	1.38	1.18
Suspended Solids	$mg.l^{-1}$		21.9	20.7	18.4	21.3	3.2	7.0	4.2	4.2	1.5<T	2.3<T	2.9	2.9	4.0	3.9	2.9	2.9
Ammonia	$mg.l^{-1}$		22.000	21.800	18.400	18.400	0.022	0.020	2.890	2.480	0.038	0.038	0.575	0.584	0.058	0.082	0.544	0.542
Total Kjeldahl Nitrogen	$mg.l^{-1}$		25.100	25.300	22.500	22.800	0.180	0.200	3.800	3.050	0.200	0.200	0.575	0.850	0.240	0.220	0.740	0.740
Total Phosphorus	$mg.l^{-1}$		0.800	0.820	0.820	0.580	0.008<T	0.010	0.118	0.100	0.009<T	0.010	0.053	0.027	0.015	0.012	0.026	0.025
Phenolics	$\mu g.l^{-1}$		55.0	80.0	38.0	38.8	0.8<W	1.0	8.4	11.2	0.8<T	1.0	2.0	1.4	3.8	2.8	8.8	11.2
Iron	$mg.l^{-1}$		0.730	0.880	0.740	0.700	0.190	0.180	0.072<T	0.074<T	0.100<T	0.0012<T	0.098<T	0.0028	0.180	0.0018<T	0.081<T	0.0007<T
Zinc	$mg.l^{-1}$		0.0310	0.0280	0.0240	0.0210	0.0019<T	0.0017<T	0.0008<T	0.0011<T	0.100<T	0.0010<T	0.110	0.0023<T	0.180	0.0020<T	0.081<T	0.0008<T
Fecal Coliforms	$org.dl^{-1}$		5500	8800	2000	2000	23<W	12	110	120	4	4	104	100	1140	1180	40	48
Eschericia coli	$org.dl^{-1}$		2700	4500	1400	1700	7<W	12	80<W	80<W	4	4	44	38	720	880	18	38
Pseudomonas aeruginosa	$org.dl^{-1}$		117<W	540	220	220	2<W	4	4<W	20	2<W	2<W	38	18	8	18	8	8

NOTES: "CV" = coefficient of variation calculated using CV = [$\sqrt{2}$(max.-min.)/(max. + min.)]*100.
* data from Sturgis (1987).
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); lessthan reported value.
"--" not available or could not be calculated.

Table A-5. continued.

Parameter	Units	Station No.:	Station 172				Station 173							
		Date:	Jun 28		Aug 24		Jun 27		Jun 29		Aug 22		Aug 23	
		m. from shore:	300		300		150		175		200		200	
		Sample No.:	83850	83851	88512	88513	83828	83829	83882	83883	88415	88418	88457	88458
Conductivity	μs.cm⁻¹		99.0	99.0	98.0	98.0	105.0	105.0	103.0	108.0	98.0	99.0	99.0	99.0
Chloride	mg.l⁻¹		1.90	1.90	1.80	1.60	2.50	3.20	3.10	3.10	1.50	1.60	1.70	1.70
pH	-log₁₀[H⁺]		7.97	7.93	7.91	7.98	7.78	7.94	7.70	7.78	7.95	7.97	7.97	7.98
Turbidity	FTU		1.85	1.54	1.25	1.42	1.80	1.50	1.24	1.28	1.12	1.05	1.84	1.31
Suspended Solids	mg.l⁻¹		3.7	0.3<W	3.4	3.3	2.8	0.5<W	5.7	1.8<T	3.0	3.1	1.4<T	1.2<T
Ammonia	mg.l⁻¹		0.032	0.049	0.070	0.070	0.196	0.308	0.242	0.232	0.070	0.072	0.102	0.102
Total Kjeldahl Nitrogen	mg.l⁻¹		0.320	0.290	0.200	0.210	0.580	0.590	0.320	0.320	0.210	0.270	0.250	0.240
Total Phosphorus	mg.l⁻¹		0.024	0.024	0.009<T	0.009<T	0.028	0.027	0.014	0.015	0.009<T	0.009<T	0.009<T	0.009<T
Phenolics	μg.l⁻¹		1.0	1.0	19.4	2.8	1.8	1.0	1.2	2.0	2.2	1.8	1.4	1.4
Iron	mg.l⁻¹		0.170	0.190	0.170	0.0019<T	0.110	0.120	0.092<T	0.082<T	0.110	0.100<T	0.088<T	0.0009<T
Zinc	mg.l⁻¹		0.0019<T	0.0020<T	0.180	0.0019<T	0.0017<T	0.0014<T	0.0021<T	0.0028	0.0010<T	0.015<T	0.072<T	0.0010<T
Fecal Coliforms	org.dl⁻¹		4<W	12	40	52	12	32	80	40	820	980	104	118
Eschericia coli	org.dl⁻¹		4<W	4	24	28	4	12	52	40	480	720	72	52
Pseudomonas aeruginosa	org.dl⁻¹		2<W	2<W	2<W	10<W	4	2	2	2	39	28	10	9

NOTES: "CV" = coefficient of variation calculated using CV = [√2(max.-min.)/(max.+min.)]*100.
* data from Sturgis (1987).
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); lessthan reported value.
"--" not available or could not be calculated.

Table A-5. continued.

Parameter	Units	Station No.:	Station 174						Station 54				Variability (CV), %		Laboratory Blank *
		Date:	Jun 27		Jun 29		Aug 23		Aug 22		Aug 23				
		m. from shore:	100		300		100		320		850				
		Sample No.:	83819	83820	83857	83858	88449	88450	88402	88403	88448	88447	Field	Laboratory *	
Conductivity	$\mu s.cm^{-1}$		88.0	98.0	95.0	95.0	97.0	87.0	97.0	97.0	96.0	98.0	0.0 to 12.4		
Chloride	$mg.l^{-1}$		1.40	1.40	1.40	1.40	1.40	1.40	1.50	1.40	1.30	1.30	0.0 to 9.28		
pH	$-log_{10}[H^+]$		7.90	7.95	7.84	7.85	7.99	8.00	7.94	7.88	8.02	8.03	0.0 to 1.44		
Turbidity	FTU		1.10	1.00	0.87	0.86	1.45	2.70	0.70	0.78	0.80	1.66	0.0 to 97.3		
Suspended Solids	$mg.l^{-1}$		1.3<T	0.8<T	1.1<T	1.0<T	3.6	3.8	2.4<T	2.2<T	2.2<T	1.8<T	0.0 to 120		
Ammonia	$mg.l^{-1}$		0.040	0.042	0.018	0.008<T	0.048	0.046	0.042	0.040	0.028	0.028	0.0 to 31.0		
Total Kjeldahl Nitrogen	$mg.l^{-1}$		0.190	0.190	0.140	0.140	0.240	0.160	0.160	0.180	0.150	0.160	0.0 to 27.3		
Total Phosphorus	$mg.l^{-1}$		0.006<T	0.008<T	0.002<W	0.002<W	0.009<T	0.009<T	0.006<T	0.008<T	0.004<T	0.005<T	0.0 to 48.0		
Phenolics	$\mu g.l^{-1}$		0.4<T	0.4<T	0.2<T	0.2<T	2.0	1.8	1.8	1.4	1.6	0.8<T	0.0 to 105		
Iron	$mg.l^{-1}$		0.061<T	0.065<T	0.037<T	0.038<T	0.110	0.100<T	0.075<T	0.076<T	0.089<T	0.087<T	0.0 to 138		
Zinc	$mg.l^{-1}$		0.0008<T	0.0007<T	0.0007<T	0.0007<T	0.0011<T	0.0011	0.0007<T	0.0008<T	0.0005<W	0.0005<W	0.0 to 138		
Fecal Coliforms	$org.dl^{-1}$		4	7	40	4	72	72	472	512	40	38	0.0 to 116		
Eschericia coli	$org.dl^{-1}$		4	7	26	4	56	46	300	388	24	32	0.0 to 108		
Pseudomonas aeruginosa	$org.dl^{-1}$		2	2<W	2	2<W	4	6	10	14	8	12	0.0 to 94.3		

NOTES: "CV" = coefficient of variation calculated using CV = [√2(max.-min.)/(max. + min.)]* 100.

* data from Sturgis (1987).

"<T" = a measurable trace amount; interpret with caution.

"<W" = no measurable response (zero); lessthan reported value.

"--" not available or could not be calculated.

Table A-6. River water samples field blank data.

Parameter	Units	Station No.:	Station 170						Station 172	Laboratory Blank
		Date:	Jun 27	Jun 28	Jun 29	Aug 22	Aug 23	Aug 24	Jun 27	
		metres from shore:	150 m	500 m	500 m	500 m	500 m	500 m	240 m	
		Sample No.:	63601	63646	63684	68439	68485	68526	63638	
Conductivity	$\mu s.cm^{-1}$		2.0	2.0	2.0	2.0<T	1.0<	2.0<T	2.0	
Chloride	$mg.l^{-1}$		0.20<W	0.20<W	0.20<W	0.20<W	0.20<W	0.20<W	3.20	
pH	$-log_{10}[H^+]$		6.21	6.13	6.23	6.17	5.69	6.07	6.07	
Turbidity	FTU		0.31	0.51	0.43	0.88	0.25	0.55	1.81	
Suspended Solids	$mg.l^{-1}$		5.3<W	0.8<T	0.7<T	1.1<T	0.4<W	0.5<T	0.5<W	
Ammonia	$mg.l^{-1}$		0.002<W	0.002<W	0.002<W	0.010	0.002<W	0.002<W	0.002<W	
Total Kjeldahl Nitrogen	$mg.l^{-1}$		0.070<T	0.050<T	0.050<T	0.040<T	0.020<W	0.030<T	0.050<T	
Total Phosphorus	$mg.l^{-1}$		0.003<T	0.008<T	0.002<W	0.003<T	0.002<W	0.002<W	0.003<T	
Phenolics	$\mu g.l^{-1}$		0.2<T	0.6<T	0.6<T	2.0	1.4	CR	1.0	
Iron	$mg.l^{-1}$		0.020<W	0.020<W	0.020<W	0.027<T	0.020<W	0.020<W	0.021<T	
Zinc	$mg.l^{-1}$		0.0026	0.0005<W	0.0010<T	0.0110	0.0039	0.0006<T	0.0034	
Fecal Coliforms	$org.dl^{-1}$			4<W	4<W	16	4<W	4<W		
Eschericia coli	$org.dl^{-1}$			4<W	4<W	16	4<W	4<W		
Pseudomonas aeruginosa	$org.dl^{-1}$			2<W	2<W	10	2<W	2<W		

NOTES: * data from Sturgis (1987).
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); less than reported value.
"--" not available or could not be calculated.

Table A-7. Sediment sample field blind duplicates (split) data.

Parameter	Units	Station 172		Station 175		Variability (CV), %		Laboratory
		68233	68234	68237	68238	Field	Laboratory *	Blank *
2000-1000 μm	%	0.30	0.30	0.10	0.10	0.0	--	--
999-62 μm	%	--	--	31.10	31.30	0.5	--	--
<62 μm	%	--	--	65.30	65.50	0.2	--	--
Moisture	%	58.0	66.0	66.0	66.0	0.0 to 9.1		
Field Density	g.cm^{-3}	1.275	1.253	1.234	1.242	0.5 to 1.2		
Faecal Coliforms	number.kg^{-1}	~1000	~2000	~1000	<1000	~47.1		
Escherichia coli	number.kg^{-1}	<1000	~1000	<1000	<1000	0.0 to ~47.1		
Faecal *Streptococcus*	number.kg^{-1}	<10000	<10000	<1000	<10000	0.0 to ~116		
Loss on Ignition	g.kg^{-1}	100.0	100.0	87.1	81.0	0.0 to 5.1	6.6	--
Total Organic Carbon	g.kg^{-1}	78.3	78.0	65.0	64.0	0.3 to 1.1	3.2	--
Total Kjeldahl Nitrogen	g.kg^{-1}	2.90	2.60	2.40	2.50	2.0 to 7.7	4.9	--
Total Phosphorus	g.kg^{-1}	1.00	0.92	0.77	0.81	3.6 to 5.9	6.0	--
Arsenic	mg.kg^{-1}	11.0	11.0	13.00	9.50	0.0 to 22.0	12.1	0.00
Cyanide, avial.	mg.kg^{-1}	0.610	1.700	1.800	2.200	14.1 to 66.7	--	--
Cyanide, free	mg.kg^{-1}	0.010<W	0.010<W	0.010<W	0.010<W	~0.0	--	--
Cadmium	mg.kg^{-1}	0.86	0.78	1.10	1.20	6.1 to 6.9	12.8	0.04
Chromium	mg.kg^{-1}	62.0	64.0	97.0	100.0	2.2	10.7	1.60
Copper	mg.kg^{-1}	59.0	61.0	67.0	64.0	2.4 to 3.2	9.4	1.26
Iron	mg.kg^{-1}	47000	46000	59000	58000	1.2 to 1.5	3.2	1.80
Lead	mg.kg^{-1}	57.0	58.0	86.0	83.0	1.2 to 2.5	7.8	1.33
Magnesium	mg.kg^{-1}	2600	2600	3600	3500	0.0 to 2.0	--	--
Manganese	mg.kg^{-1}	530	520	600	600	0.0 to 1.3	--	--
Mercury	mg.kg^{-1}	0.32	0.28	0.28	0.30	4.9 to 9.4	10.6	--
Nickel	mg.kg^{-1}	22.0	21.0	23.0	23.0	0.0 to 3.3	5.1	0.98
Zinc	mg.kg^{-1}	200.0	210.0	290.0	280.0	3.4 to 2.5	9.5	7.32
Solvent Extractables	mg.kg^{-1}	4295	3078	2226	1587	23.3 to 23.7	--	--
Acenaphthene	mg.kg^{-1}	0.10	0.13	0.06	0.05<T	12.9 to 18.4		
Acenaphthylene	mg.kg^{-1}	0.13	0.12	0.20	0.17	6.1 to 11.5		
Anthracene	mg.kg^{-1}	0.37	0.41	0.34	0.30	7.2 to 8.8		
Benz(a)anthracene	mg.kg^{-1}	1.00	1.80	1.50	1.10	21.8 to 40.4		
Benzo(b)fluoranthene	mg.kg^{-1}	1.50	2.30	2.70	1.80	28.2 to 29.8		
Benzo(k)fluoranthene	mg.kg^{-1}	0.720	0.850	1.20	0.86	11.7 to 23.3		
Benzo(g,h,i)perylene	mg.kg^{-1}	0.77	0.57	1.00	0.90	7.4 to 21.1		
Benzo(a)pyrene	mg.kg^{-1}	1.10	0.96	2.10	1.40	9.6 to 28.3		
Chrysene	mg.kg^{-1}	1.40	1.80	2.20	1.60	17.7 to 22.3		
Dibenzo(a,h)anthracene	mg.kg^{-1}	0.26	0.21	0.38	0.32	12.1 to 15.0		
Fluoranthene	mg.kg^{-1}	2.50	3.10	3.00	2.40	15.2 to 15.7		
Fluorene	mg.kg^{-1}	0.14	0.14	0.11	0.10	0.0 to 6.7		
Indeno(1,2,3-cd)pyrene	mg.kg^{-1}	0.86	0.84	1.20	1.10	1.7 to 6.1		
Naphthalene	mg.kg^{-1}	0.81	0.57	0.42	0.36	10.9 to 24.6		
Phenanthrene	mg.kg^{-1}	1.30	1.30	1.00	0.91	0.0 to 6.7		
Pyrene	mg.kg^{-1}	2.20	2.50	2.70	2.10	9.0 to 17.7		
D_{10}-Acenaphthene recovery	%	73	62	53	53	--	--	
D_{12}-Chrysene recovery	%	93	99	115	96	--	--	
D_8-Naphthalene recovery	%	36	44	20	20	--	--	
D_{12}-Perylene recovery	%	118	163	140	115	--	--	
D_{10}-Phenanthrene recovery	%	90	90	74	72	--	--	

NOTES: "CV" = coefficient of variation calculated using CV = [√2(max.-min.)/(max.+min.)]*100
* data from Sturgis (1987).
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); less than reported value.
"--" not available or could not be calculated.

Table A-8. Sediment sample field replicates data.

Parameter	Units	Station 172			Station 174			Variability (CV), %		Lab. %
		68228	68229	68230	68242	68243	68244	Field	Lab. *	Recovery *
2000-1000 μm	%	0.1	0.1	0.1	0.3	0.1	0.1	0.0 to 69.3	--	--
999-62 μm	%	49.6	34.1	49.1	73.8	54.8	45.4	19.9 to 24.9	--	--
<62 μm	%	48.6	63.6	50.6	25.8	41.2	52.7	15.0 to 33.8	--	--
Moisture	%	57.0	67.0	59.0	57.0	61.0	61.0	3.9 to 8.7		
Field Density	g.cm^{-3}	1.321	1.226	1.302	1.347	1.291	1.317	2.1 to 3.9		
Faecal Coliforms	number.kg^{-1}	<1000	<1000	~1000	~8000	10000	~30000	~43.3 to 76.0		
Escherichia coli	number.kg^{-1}	<1000	<1000	<1000	~1000	~3000	<1000	~0.0 to 88.2		
Faecal *Streptococcus*	number.kg^{-1}	<10000	<10000	<1000	<10000	<1000	<1000	~74.2 to 130		
Loss on Ignition	g.kg^{-1}	47.0	81.0	48.0	62.0	76.0	77.0	11.7 to 33.0	7.1	--
Total Organic Carbon	g.kg^{-1}	35.0	57.0	35.0	51.0	62.0	56.0	9.8 to 30.0	2.7	--
Total Kjeldahl Nitrogen	g.kg^{-1}	1.90	2.70	1.80	0.82	1.10	0.80	18.5 to 23.1	4.9	--
Total Phosphorus	g.kg^{-1}	0.57	0.75	0.55	0.50	0.58	0.46	11.9 to 17.7	3.5	--
Arsenic	mg.kg^{-1}	6.90	12.00	7.20	5.40	6.80	9.70	30.0 to 32.9	14.3	--
Cyanide, avial	mg.kg^{-1}	0.780	1.400	0.370	0.930	0.910	1.800	41.9 to 61.0	--	--
Cyanide, free	mg.kg^{-1}	0.010<W	0.019<T	0.010<W	0.019<T	0.019<T	0.020<T	3.0 to 173	--	--
Cadmium	mg.kg^{-1}	0.88	0.23<T	0.70	0.67	0.67	0.84	13.5 to 55.6	6.5	--
Chromium	mg.kg^{-1}	72.0	16.0	49.0	69.0	89.0	73.0	13.7 to 61.6	11.6	--
Copper	mg.kg^{-1}	51.0	10.0	37.0	42.0	47.0	62.0	20.7 to 63.8	9.7	--
Iron	mg.kg^{-1}	40000	13000	25000	35000	43000	48000	15.6 to 52.0	4.7	--
Lead	mg.kg^{-1}	90.0	11.0	63.0	52.0	57.0	57.0	5.2 to 73.5	10.1	--
Magnesium	mg.kg^{-1}	3000	8900	2200	2600	2700	2800	3.7 to 85.3	--	--
Manganese	mg.kg^{-1}	380	330	260	290	390	530	18.6 to 29.9	--	--
Mercury	mg.kg^{-1}	0.24	0.33	0.19	0.22	0.26	0.25	8.6 to 28.0	7.6	--
Nickel	mg.kg^{-1}	28.0	10.0	13.0	14.0	16.0	20.0	18.3 to 56.7	10.0	--
Zinc	mg.kg^{-1}	290.0	50.0	190.0	130.0	170.0	230.0	28.5 to 68.2	9.7	--
Solvent Extractables	mg.kg^{-1}	3608	5131	2998	351	370	1489	28.1 to 88.5	--	--
Acenaphthene	mg.kg^{-1}	0.04<T	0.04<T	0.04<T	0.05<T	0.06	0.05<T	0.0 to 10.8		
Acenaphthylene	mg.kg^{-1}	0.06	0.11	0.07	0.10	0.19	0.18	31.5 to 33.1		
Anthracene	mg.kg^{-1}	0.10	0.18	0.10	0.26	0.31	0.39	20.5 to 36.5		
Benz(a)anthracene	mg.kg^{-1}	0.48	0.64	0.68	0.92	0.94	1.60	17.6 to 33.6		
Benzo(b)fluoranthene	mg.kg^{-1}	1.00	1.00	1.80	1.20	1.40	3.30	36.5 to 58.9		
Benzo(k)fluoranthene	mg.kg^{-1}	0.30	0.45	0.43	0.42	0.69	1.10	20.7 to 46.5		
Benzo(g,h,i)perylene	mg.kg^{-1}	0.27	0.57	0.23	0.35	0.74	0.82	39.5 to 52.1		
Benzo(a)pyrene	mg.kg^{-1}	0.55	0.75	0.96	0.82	1.10	2.20	27.2 to 53.1		
Chrysene	mg.kg^{-1}	0.80	0.91	1.20	1.00	1.30	2.30	21.3 to 44.4		
Dibenzo(a,h)anthracene	mg.kg^{-1}	0.08	0.18	0.08	0.14	0.26	0.32	38.2 to 50.9		
Fluoranthene	mg.kg^{-1}	1.10	1.80	1.20	1.80	2.10	2.90	25.1 to 27.7		
Fluorene	mg.kg^{-1}	0.05	0.08	0.05	0.09	0.13	0.11	18.2 to 28.9		
Indeno(1,2,3-cd)pyrene	mg.kg^{-1}	0.30	0.62	0.27	0.42	0.78	0.89	35.3 to 48.9		
Naphthalene	mg.kg^{-1}	0.16	0.19	0.18	0.34	0.70	0.37	17.7 to 42.5		
Phenanthrene	mg.kg^{-1}	0.39	0.68	0.40	0.75	0.94	1.00	14.6 to 33.6		
Pyrene	mg.kg^{-1}	0.94	1.50	1.10	1.50	1.90	2.50	24.4 to 25.6		
D_{10}-Acenaphthene recovery	%	76	59	79	64	68	60	--	--	
D_{12}-Chrysene recovery	%	86	98	104	75	104	125	--	--	
D_8-Naphthalene recovery	%	42	26	45	38	28	17	--	--	
D_{12}-Perylene recovery	%	90	119	99	76	130	140	--	--	
D_{10}-Phenanthrene recovery	%	92	75	86	84	87	88	--	--	

NOTES: "CV" = coefficient of variation [(Std Dev./Mean)*100].
* data from Sturgis (1987).
"<T" = a measurable trace amount; interpret with caution.
"<W" = no measurable response (zero); less than reported value.
"--" not available or could not be calculated.

Table A-9. Sediment parameter correlation coefficients. Pearson Product-Moment analysis on log (x+1)-transformed concentration data; percentages were arc sin√x-transformed. Significant correlations at $p < 0.05$ are underlined ($n = 16$).

	Dist	Fines	Moist	LOI	TOC	TP	TKN	As	Cd	Cr	Cu	CN	Fe	Pb	Mn	Mg	Hg	Ni	Zn	SolExt	Ace	Acny	Anth
Dist	1.00	0.24	0.58	0.55	0.31	-0.27	0.49	0.69	0.30	0.24	0.43	0.40	0.38	0.40	0.30	0.07	0.20	0.34	0.44	0.38	0.38	0.10	0.35
Fines	0.24	1.00	0.74	0.58	0.09	-0.37	0.80	0.56	0.28	0.10	0.28	0.60	0.03	0.27	0.08	0.26	0.18	0.18	0.25	0.26	0.11	0.29	0.11
Moist	0.56	0.74	1.00	0.88	0.40	-0.31	0.66	0.86	0.52	0.44	0.62	0.81	0.45	0.54	0.39	0.14	0.45	0.43	0.56	0.30	0.56	0.56	0.60
LOI	0.55	0.58	0.88	1.00	0.66	-0.05	0.81	0.87	0.44	0.47	0.52	0.77	0.49	0.44	0.44	0.12	0.55	0.36	0.52	0.44	0.63	0.64	0.71
TOC	0.31	0.09	0.40	0.66	1.00	0.62	0.28	0.40	-0.05	0.25	0.15	0.29	0.25	-0.01	0.12	-0.14	0.31	-0.02	0.09	0.71	0.20	0.29	0.38
TP	-0.27	-0.37	-0.31	-0.05	0.62	1.00	-0.31	-0.36	-0.53	-0.23	-0.38	-0.36	-0.27	-0.49	-0.38	-0.40	-0.02	-0.47	-0.44	0.39	-0.38	-0.24	-0.26
TKN	0.49	0.80	0.86	0.81	0.28	-0.31	1.00	0.81	0.45	0.29	0.48	0.71	0.31	0.47	0.32	0.22	0.52	0.35	0.49	0.40	0.49	0.44	0.45
As	0.69	0.58	0.86	0.87	0.40	-0.36	0.81	1.00	0.61	0.53	0.69	0.85	0.62	0.61	0.59	0.31	0.45	0.55	0.66	0.26	0.63	0.63	0.72
Cd	0.30	0.28	0.52	0.44	-0.05	-0.53	0.45	0.61	1.00	0.89	0.91	0.75	0.88	0.95	0.90	0.75	0.50	0.94	0.96	-0.13	0.48	0.75	0.69
Cr	0.24	0.10	0.44	0.47	0.25	-0.23	0.29	0.53	0.89	1.00	0.88	0.69	0.96	0.88	0.93	0.70	0.56	0.90	0.92	-0.01	0.44	0.85	0.80
Cu	0.43	0.28	0.62	0.52	0.15	-0.38	0.48	0.69	0.91	0.88	1.00	0.84	0.91	0.92	0.88	0.67	0.52	0.93	0.93	0.06	0.52	0.72	0.71
CN	0.40	0.60	0.81	0.77	0.29	-0.36	0.71	0.85	0.75	0.69	0.84	1.00	0.71	0.78	0.68	0.46	0.60	0.69	0.78	0.16	0.53	0.78	0.71
Fe	0.38	0.03	0.45	0.49	0.25	-0.27	0.31	0.62	0.88	0.96	0.91	0.71	1.00	0.88	0.97	0.65	0.55	0.91	0.93	0.01	0.54	0.80	0.63
Pb	0.40	0.27	0.54	0.44	-0.01	-0.49	0.47	0.61	0.95	0.88	0.92	0.78	0.88	1.00	0.86	0.68	0.65	0.92	0.98	-0.05	0.42	0.74	0.67
Mn	0.30	0.08	0.39	0.44	0.12	-0.38	0.32	0.59	0.90	0.93	0.88	0.68	0.97	0.86	1.00	0.77	0.47	0.95	0.92	-0.05	0.57	0.78	0.81
Mg	0.07	0.26	0.14	0.12	-0.14	-0.40	0.22	0.31	0.75	0.70	0.67	0.46	0.65	0.68	0.77	1.00	0.15	0.63	0.69	-0.04	0.13	0.47	0.33
Hg	0.20	0.18	0.45	0.55	0.31	-0.02	0.52	0.45	0.50	0.56	0.52	0.60	0.55	0.65	0.47	0.15	1.00	0.41	0.63	0.19	0.31	0.65	0.58
Ni	0.34	0.18	0.43	0.36	-0.02	-0.47	0.35	0.55	0.94	0.90	0.93	0.69	0.91	0.92	0.95	0.63	0.41	1.00	0.94	-0.05	0.49	0.69	0.67
Zn	0.44	0.25	0.56	0.52	0.09	-0.44	0.49	0.66	0.96	0.92	0.93	0.78	0.93	0.96	0.92	0.69	0.63	0.94	1.00	-0.00	0.50	0.77	0.74
SolExt	0.38	0.26	0.30	0.44	0.71	0.39	0.40	0.26	-0.13	-0.01	0.06	0.16	0.01	-0.05	-0.05	-0.04	0.19	-0.05	-0.00	1.00	0.06	-0.12	-0.02
Ace	0.38	0.11	0.56	0.63	0.20	-0.38	0.49	0.63	0.48	0.44	0.52	0.53	0.54	0.42	0.57	0.13	0.31	0.49	0.50	0.06	1.00	0.55	0.79
Acny	0.10	0.29	0.56	0.64	0.29	-0.24	0.44	0.63	0.75	0.85	0.72	0.78	0.80	0.74	0.78	0.47	0.65	0.69	0.77	-0.12	0.55	1.00	0.89
Anth	0.35	0.11	0.60	0.71	0.38	-0.26	0.45	0.72	0.69	0.80	0.71	0.71	0.83	0.67	0.81	0.33	0.58	0.67	0.74	-0.02	0.79	0.89	1.00
BaAnth	0.30	0.27	0.62	0.70	0.28	-0.32	0.56	0.74	0.79	0.84	0.75	0.77	0.63	0.77	0.63	0.50	0.67	0.73	0.82	-0.07	0.65	0.94	0.94
BbFluo	0.20	0.34	0.59	0.67	0.27	-0.29	0.57	0.69	0.77	0.82	0.71	0.75	0.78	0.75	0.79	0.55	0.70	0.70	0.79	-0.05	0.56	0.94	0.87
BkFluo	0.16	0.38	0.62	0.67	0.24	-0.29	0.60	0.67	0.80	0.83	0.74	0.77	0.78	0.77	0.80	0.56	0.69	0.73	0.81	-0.07	0.54	0.94	0.85
BghiP	0.12	0.37	0.63	0.68	0.27	-0.27	0.60	0.68	0.81	0.84	0.75	0.79	0.79	0.77	0.79	0.53	0.70	0.71	0.80	-0.04	0.56	0.95	0.86
BaP	0.16	0.36	0.60	0.66	0.24	-0.31	0.56	0.69	0.80	0.85	0.74	0.79	0.80	0.78	0.82	0.57	0.69	0.72	0.81	-0.09	0.52	0.96	0.87
Chry	0.25	0.32	0.61	0.70	0.29	-0.31	0.57	0.73	0.79	0.84	0.73	0.78	0.81	0.77	0.82	0.54	0.69	0.72	0.81	-0.04	0.60	0.95	0.91
DahAnth	0.11	0.34	0.62	0.64	0.24	-0.27	0.56	0.65	0.80	0.84	0.75	0.77	0.79	0.78	0.78	0.49	0.71	0.70	0.80	-0.09	0.52	0.96	0.86
Flan	0.40	0.27	0.65	0.74	0.31	-0.37	0.57	0.81	0.77	0.81	0.74	0.78	0.83	0.75	0.83	0.45	0.63	0.71	0.80	-0.03	0.71	0.91	0.96
Fluo	0.34	0.16	0.66	0.80	0.51	-0.15	0.50	0.73	0.53	0.66	0.62	0.70	0.70	0.51	0.67	0.18	0.54	0.52	0.59	0.13	0.65	0.62	0.95
IndP	0.12	0.35	0.62	0.67	0.28	-0.24	0.60	0.66	0.79	0.63	0.73	0.76	0.78	0.75	0.78	0.51	0.71	0.70	0.79	-0.02	0.56	0.94	0.86
Naph	0.25	-0.04	0.45	0.64	0.62	0.12	0.27	0.50	0.36	0.57	0.46	0.44	0.60	0.30	0.54	0.12	0.31	0.39	0.42	0.28	0.75	0.61	0.77
Phen	0.45	0.20	0.68	0.77	0.38	-0.32	0.55	0.62	0.71	0.77	0.75	0.78	0.83	0.70	0.80	0.34	0.60	0.68	0.77	0.04	0.62	0.86	0.96
Pyr	0.36	0.27	0.64	0.72	0.29	-0.37	0.56	0.79	0.79	0.83	0.75	0.78	0.84	0.76	0.84	0.48	0.64	0.73	0.62	-0.05	0.70	0.93	0.96
TPAHs	0.40	0.26	0.67	0.77	0.39	-0.29	0.56	0.62	0.75	0.62	0.75	0.78	0.85	0.73	0.83	0.44	0.63	0.70	0.80	0.04	0.72	0.90	0.97

Table A-9. continued.

	BaAnth	BbFluo	BkFluo	BghiP	BaP	Chry	DahAnth	Flan	Fluo	IndP	Naph	Phen	Pyr	TPAHs
Dist	0.30	0.20	0.16	0.12	0.16	0.25	0.11	0.40	0.34	0.12	0.25	0.45	0.36	0.40
Fines	0.27	0.34	0.38	0.37	0.36	0.32	0.34	0.27	0.16	0.35	-0.04	0.20	0.27	0.26
Moist	0.62	0.59	0.62	0.63	0.60	0.61	0.62	0.65	0.66	0.62	0.45	0.68	0.64	0.67
LOI	0.70	0.67	0.67	0.68	0.66	0.70	0.64	0.74	0.80	0.67	0.64	0.77	0.72	0.77
TOC	0.28	0.27	0.24	0.27	0.24	0.29	0.24	0.31	0.51	0.28	0.62	0.38	0.29	0.39
TP	-0.32	-0.29	-0.29	-0.27	-0.31	-0.31	-0.27	-0.37	-0.15	-0.24	0.12	-0.32	-0.37	-0.29
TKN	0.56	0.57	0.60	0.60	0.56	0.57	0.56	0.57	0.50	0.60	0.27	0.55	0.56	0.58
As	0.74	0.69	0.67	0.68	0.69	0.73	0.65	0.81	0.73	0.66	0.50	0.82	0.79	0.82
Cd	0.79	0.77	0.80	0.81	0.80	0.79	0.80	0.77	0.53	0.79	0.36	0.71	0.79	0.75
Cr	0.84	0.82	0.83	0.84	0.85	0.84	0.84	0.81	0.66	0.83	0.57	0.77	0.83	0.82
Cu	0.75	0.71	0.74	0.75	0.74	0.73	0.75	0.74	0.62	0.73	0.46	0.75	0.75	0.75
CN	0.77	0.75	0.77	0.79	0.79	0.78	0.77	0.78	0.70	0.76	0.44	0.78	0.78	0.78
Fe	0.83	0.78	0.78	0.79	0.80	0.81	0.79	0.83	0.70	0.78	0.60	0.83	0.84	0.85
Pb	0.77	0.75	0.77	0.77	0.78	0.77	0.78	0.75	0.51	0.75	0.30	0.70	0.76	0.73
Mn	0.83	0.79	0.80	0.79	0.82	0.82	0.78	0.83	0.67	0.78	0.54	0.80	0.84	0.83
Mg	0.50	0.55	0.56	0.53	0.57	0.54	0.49	0.45	0.18	0.51	0.12	0.34	0.48	0.44
Hg	0.67	0.70	0.69	0.70	0.69	0.69	0.71	0.63	0.54	0.71	0.31	0.60	0.64	0.63
Ni	0.73	0.70	0.73	0.71	0.72	0.72	0.70	0.71	0.52	0.70	0.39	0.68	0.73	0.70
Zn	0.82	0.79	0.81	0.80	0.81	0.81	0.80	0.80	0.59	0.79	0.42	0.77	0.82	0.80
SolExt	-0.07	-0.05	-0.07	-0.04	-0.09	-0.04	-0.09	-0.03	0.13	-0.02	0.28	0.04	-0.05	0.04
Ace	0.65	0.56	0.54	0.56	0.52	0.60	0.52	0.71	0.85	0.56	0.75	0.82	0.70	0.72
Acny	0.94	0.94	0.94	0.95	0.96	0.95	0.96	0.91	0.82	0.94	0.61	0.86	0.93	0.90
Anth	0.94	0.87	0.85	0.86	0.87	0.91	0.86	0.96	0.95	0.86	0.77	0.98	0.96	0.97
BaAnth	1.00	0.98	0.97	0.96	0.97	0.99	0.95	0.98	0.85	0.96	0.58	0.94	0.99	0.97
BbFluo	0.98	1.00	0.98	0.97	0.99	0.99	0.96	0.95	0.78	0.97	0.54	0.87	0.96	0.94
BkFluo	0.97	0.98	1.00	0.99	0.99	0.98	0.98	0.92	0.76	0.99	0.49	0.85	0.94	0.91
BghiP	0.96	0.97	0.99	1.00	0.99	0.97	0.99	0.92	0.78	1.00	0.55	0.86	0.93	0.92
BaP	0.97	0.99	0.99	0.99	1.00	0.99	0.98	0.94	0.77	0.98	0.52	0.86	0.95	0.93
Chry	0.99	0.99	0.98	0.97	0.99	1.00	0.96	0.97	0.82	0.97	0.56	0.91	0.98	0.96
DahAnth	0.95	0.96	0.98	0.99	0.98	0.96	1.00	0.91	0.76	0.99	0.51	0.84	0.92	0.90
Flan	0.98	0.95	0.92	0.92	0.94	0.97	0.91	1.00	0.89	0.91	0.63	0.97	1.00	0.99
Fluo	0.85	0.78	0.76	0.78	0.77	0.82	0.76	0.89	1.00	0.78	0.85	0.95	0.88	0.91
IndP	0.96	0.97	0.99	1.00	0.98	0.97	0.99	0.91	0.78	1.00	0.55	0.85	0.93	0.91
Naph	0.58	0.54	0.49	0.55	0.52	0.56	0.51	0.63	0.85	0.55	1.00	0.75	0.62	0.70
Phen	0.94	0.87	0.85	0.86	0.86	0.91	0.84	0.97	0.95	0.85	0.75	1.00	0.96	0.98
Pyr	0.99	0.96	0.94	0.93	0.95	0.98	0.92	1.00	0.88	0.93	0.62	0.96	1.00	0.99
TPAHs	0.97	0.94	0.91	0.92	0.93	0.96	0.90	0.99	0.91	0.91	0.70	0.98	0.99	1.00